HIGH SCHOOL
AGRICULTURE

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FARMING PAYS.

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AGRICULTURE

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PREFACE

THE character of agriculture as a fundamental science, as well as the fact that it is the primary interest of a vast majority of the citizens of our country, makes it the most favorable vocational subject for general adoption in secondary schools. There are in present use many elementary treatises on this subject, the use of which has created a strong demand for a more advanced course in agriculture. Just what such a course should include and how the work should be presented are questions that will be answered by many authors in many different ways in the next few years.

Since agriculture involves the elementary principles of so many sciences, and since its study interprets so much of the student's environment, making it full of meaning, we believe that the subject should be studied in the *first years* of the secondary course. It presents an interesting introduction to all the natural sciences and directs the mind of the student inquiringly toward the further study of the problems of these involved sciences. It answers in the very beginning the proper question of the boy, " Of what use is the study of chemistry, of botany, and of zoölogy ? "

The time has come to undertake the study of agriculture seriously, and not merely as a means to glorify country life and to arouse enthusiasm for the possibilities of farm endeavor. Students should feel that certain definite principles should be mastered and their application understood. Yet this subject should not be made so ultra scientific that these students shall

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be forced through the long process of laboratory method to re-discover what scientists have fully established. There can be no real substitute for the farm or the garden as a practical laboratory. On this account we have given very few experiments to be performed by the students.

The order of the main topics as given in the text is logical, but it may be varied to suit special conditions. A very elementary agricultural chemistry is given first, because the names of the elements directly concerned in plant life, and somewhat of a familiarity with them, serve as a basis for all agricultural teaching. It also renders possible the use for reference of a larger number of more advanced textbooks and articles by scientists than would otherwise be available. Familiarity with the elements and with selected compounds is the purpose rather than adherence to applications that are directly related to agriculture. If chemical laboratories are accessible for use, some of the experiments given and others to be dictated by the teacher may well be performed by the student, but excellent results for the purpose here intended may be secured if the experiments are performed by the teacher before the class.

It is not expected that this textbook will meet all the conditions in all schools, and it is hoped that in no school will it be pursued as a complete treatise on the general subject of agriculture. Certain parts should be amplified and others eliminated from class consideration according to local demands and the interest and ability of the class.

If a real interest in the theory and practice of agriculture is stimulated and a basis for the understanding of the literature of the subject is furnished, we feel that the utmost that can be expected from a course in a secondary school has been achieved.

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HIGH SCHOOL AGRICULTURE

CHAPTER I

THE ELEMENTS OF PLANT FOOD

Elements. — All substances in the universe are composed of certain elements. About eighty of the elements[1] are familiar to chemists. Of this number there are ten which are of chief importance in explaining the composition of the soil and the growth of plant and animal life.

The Most Important Ten Elements. —

Oxygen	O	Potassium, K (L. *Kalium*)
Hydrogen	H	Iron . . Fe (L. *Ferrum*)
Nitrogen	N	Calcium . . . . Ca
Carbon	C	Magnesium . . . Mg
Phosphorus	P	Sulphur . . . . S

To these may be added four others that are of less importance: (1) Chlorine, Cl; (2) Sodium, Na; (3) Aluminium, Al; and (4) Silicon, Si.

Compounds. — A substance formed by the union of two or more elements is called a compound. Most of the substances that we see and handle are compounds. Water is a compound made by the union of the element hydrogen and the element oxygen. Sugar and starch

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[1] A list of known elements with their symbols will be found in the Appendix.

are compounds formed by the union of the elements carbon, oxygen, and hydrogen.

Mixtures. — Sometimes these elements, although associated intimately, do not combine. Air is a good illustration of a mixture of elements which do not form a single chemical compound. It is composed of the elements oxygen, nitrogen, and carbon dioxide, with small quantities of water vapor and several other less important compounds. If oxygen and nitrogen are united to form a compound, as hydrogen and oxygen are united to form water, they form a substance which is different from either of the elements.

Molecules. — According to the generally accepted theory, all bodies are composed of very minute particles, called molecules. The molecules are so small that they cannot be seen separately even by the highest power microscope. They are the smallest particles of matter that can exist alone and still hold the characteristics of the body of which they are a part.

A molecule of water, then, is the smallest particle of water that can exist and still remain water. If it became any smaller than the molecule, it would cease to exist as water, and would return to the elements oxygen and hydrogen, of which water is composed.

The Atom. — The atom is one of the parts of which a molecule is composed. Nearly every molecule is composed of two or more atoms. The molecule of water is composed of two atoms of hydrogen and one of oxygen; the cane sugar molecule consists of twelve atoms of carbon, twenty-two atoms of hydrogen, and eleven atoms of oxygen, while the molecule of oxygen consists of two atoms of oxygen.

Two Kinds of Changes. — When any change takes place of such a nature as to change the molecule, that is, to break up the molecule into atoms or to make the atoms form new combinations, this change is called a chemical change. Any change that does not alter the composition of the molecule is called a physical change.

Sugar is composed of molecules made by the combination of carbon, oxygen, and hydrogen. Sugar may be pulverized, it may be ground to finest powder, it may be dissolved in water, but it still remains sugar. The molecules are sugar molecules. Such changes are physical changes. If, however, we hold the sugar over a flame till it burns, the molecules of sugar are destroyed, but other combinations of the elements which were in the sugar pass off into the air. There is nothing left of it as sugar.

Chemical Affinity. — The tendency of the atoms of certain elements to combine, under favorable conditions, with the atoms of certain other elements is called chemical affinity. The atoms of certain elements when brought into intimate relations with the atoms of certain other elements have a strong affinity for them. It is this attraction that holds the atoms together in a molecule of water and prevents them from separating into two elements, hydrogen and oxygen. It is by this attraction that under the influence of sunlight the atoms in certain compounds find stronger affinities in atoms of other compounds than in their present compound, and new compounds are formed, resulting in growth of plant life and in decay.

It takes but little imagination to see these warring affinities asserting themselves in the molecules of every

substance. Under some conditions the changes are more active, but affinity never ceases to be present.

Light, heat, and electricity are influences that aid in the separation of the atoms of one compound and the forming of others. Most compounds are destroyed at very high temperatures and remain unchanged at very low temperatures. Under these potent influences chemical changes are going on about us all the time.

Chemists have agreed on certain symbols which shall represent an atom of the element. This symbol is usually the first letter or the first and second letters of the name of the element, but to avoid confusion some elements have for symbols the first and second letters of their Latin names; thus, P represents the atom of phosphorus and K (from Latin *kalium*) represents an atom of potassium.

A compound is represented by the symbols of its elements written one after the other. HCl represents one atom of hydrogen (H) combined with one atom of chlorine (Cl), making one molecule of hydrochloric acid. If more than one atom of an element is present in the molecule of a compound, as in phosphoric acid (H_3PO_4), a small subscript is used. H_3PO_4 means that the molecule of phosphoric acid is composed of three atoms of hydrogen (H), one atom of phosphorus (P), and four atoms of oxygen (O).

A coefficient placed before an element or a compound indicates a number of atoms or molecules. Thus, 2 Cl indicates that two atoms of chlorine are meant; 5 NaCl indicates that five molecules of sodium chloride, or common salt, are meant, making ten atoms represented.

Exercise. — Read the following symbols, telling the number of atoms indicated in each symbol: S, Fe, 2 N, O, H, CO_2, 7 HCl, HNO_3, P_2O_5, 5 H_3PO_4, 2 NaCl, 7 MgO, $CaCO_3$, 4 NaCl, Al_2O_3.

Note. — In ordinary composition scientific books do not use the symbol in place of the term which it represents. In order to familiarize the learner with the symbols, we have in this book used the symbol alone in many cases.

Chemical Equations. — Chemical action, or reaction between substances, is represented by equations. If we mix iron filings (Fe) and fine sulphur (S) and then heat the mixture in a spoon over a hot flame, chemical action takes place. The iron unites with the sulphur, making a compound called iron sulphide. This union may be represented thus: $Fe + S = FeS$. It may be interpreted one atom of iron *combined with* one atom of sulphur is converted into one molecule of iron sulphide. The above is a very simple equation. Suppose we mix the FeS formed in the above experiment with hydrochloric acid, — we shall then have the following reaction:

Iron sulphide   Hydrochloric acid   Iron chloride   Hydrogen sulphide

$$FeS + 2\,HCl = FeCl_2 + H_2S$$
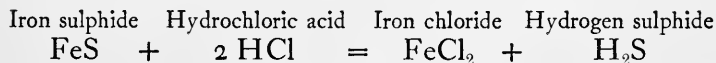
In this case one molecule of FeS is acted on by two molecules of HCl and is converted into one molecule of $FeCl_2$ and one molecule of H_2S. Note that the sum of the atoms before the sign of equality is the same as the sum of the atoms after the sign; that is, we have exactly the same number of atoms, but arranged in different groups. Changes both physical and chemical may take place, but there is just the same amount of matter in existence after as there was before the

change. It must not be supposed that a chemical equation may be made up of any combination of elements that will make an equation. On the contrary, the equation represents a chemical change and comparatively few chemical changes are possible. These must be determined by experiment.

OXYGEN (O)

Description and Occurrence. — Free oxygen is an invisible gas. It makes up more than one fifth of the
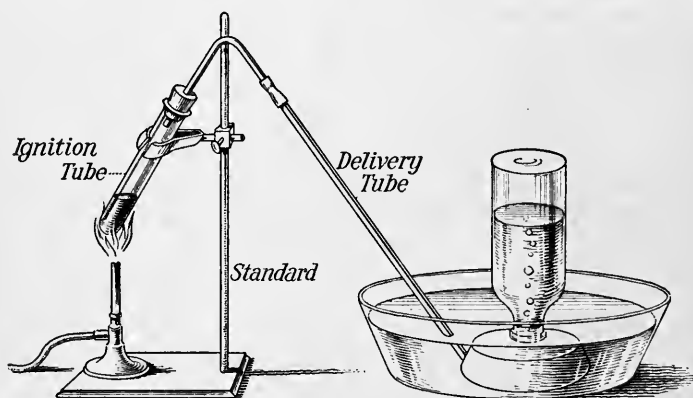
FIG. 1. — Preparing Oxygen.

air, in which it remains uncombined with other elements. It exists in combination with many other elements. For instance, with hydrogen (H) it combines to form water. By weight it is eight ninths of water. It forms three fourths of all animal bodies and about one half of the crust of the earth. Speaking generally, oxygen forms about one half of all matter.

**Preparation.** — Although oxygen is so abundant in

the air, it is difficult to separate it from the nitrogen with which it is thoroughly mixed. It may be more easily obtained from one of its compounds by the application of heat. Mercuric oxide (HgO) may be used for this purpose. Put about a tablespoonful of mercuric oxide in an ignition tube. Fit the tube with a perforated cork and a delivery tube leading underneath a shelf made by a pan (Fig. 1) with an opening in its side and another in its bottom. Invert the pan in another and deeper pan. Pour in water till the bottom of the small inverted pan is covered. Fill a glass jar with water, cover it with a glass plate, and invert it over the hole in the bottom of the smaller pan, withdrawing the glass plate under water. Now when the delivery tube is in place, as shown in Figure 1, apply heat to the mercuric oxide in the tube, and the oxygen will be separated from the mercury. The oxygen passes through the delivery tube, and bubbles of it arising through the water in the jar displace the water. This method of collecting a gas is called *collecting over water*. When the water is all displaced, the jar is full of oxygen (O); a piece of glass or the hand may be placed under the jar and the jar placed upright.

The reaction is represented as follows :

$$2\,HgO = 2\,Hg + O_2$$
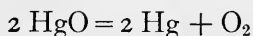
Another more common method of procuring oxygen for experimental purposes is to obtain it from potassium chlorate ($KClO_3$). Use the same apparatus as that just described. About one tablespoonful of $KClO_3$ mixed with an equal quantity of manganese dioxide (MnO_2) may be placed in the ignition tube and heated as before. The manganese dioxide does not give up its

oxygen, but in some way not well understood it causes the $KClO_3$ to give up its oxygen at a lower temperature.

$$2 KClO_3 = 2 KCl + 3 O_2$$
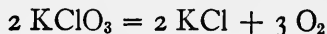
By having jars filled with water ready to slip over the opening, two or three jars of O may be obtained.

Notes. — (*a*) Many schools are now equipped with pneumatic troughs and other chemical apparatus. Where such is the case, students will not need to construct the apparatus here described.

(*b*) If a large amount of oxygen is desired for class use or for other purposes, it is better to buy it of those who make a business of preparing it. It is shipped in strong metal cylinders into which it has been compressed.

Chemical Properties. — Oxygen is very active chemically and combines with nearly every other element. This combination with other elements is called oxidation, and the products of the action are called oxides. Oxidation may take place rapidly, as in the burning of wood in a fire, or it may take place very slowly, as in the decay of wood, the rusting of iron, or the decay of the tissues of animal and vegetable matter.

A glowing splinter of wood thrust into a jar of oxygen will suddenly burst into flame and burn rapidly. This is the common test for oxygen. The reaction is expressed:

Carbon + Oxygen   Carbon dioxide
$$C + O_2 \qquad = \qquad CO_2$$
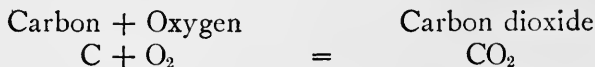
The splinter will continue to burn till the oxygen is used up or till the wood is entirely consumed.

Make a little cup in the end of a piece of crayon, wrap the end of a piece of wire about 8 inches in length about

the crayon, so that the crayon may be lowered into a jar. Place a piece of sulphur the size of a pea in the cup, touch it with a piece of hot iron so that it begins to burn in the air. Lower it into a jar of oxygen and note the beautiful blue flame.

Reaction: $S + O_2 = SO_2$
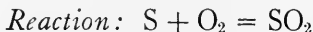
Fray out the end of a picture cord wire, heat the frayed end to redness, dip it quickly into flour of sulphur, and then into a jar of O. The sulphur sticking to the cord starts the combustion of the

FIG. 2. — Sulphur burning in Oxygen.

iron and the oxygen continues it so that the entire cord may be burned, producing very brilliant scintillations.
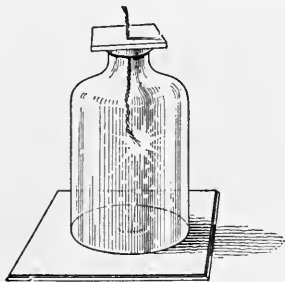
FIG. 3. — Wire burning in Oxygen.

A little water should be in the jar to prevent the burning globules of iron from melting or cracking the glass jar.

Reaction: $3 Fe + 2 O_2 = Fe_3O_4$
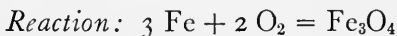
The experiments just described illustrate the effects of oxygen when unmixed with nitrogen, but oxygen is also a constantly active agent in all the processes of life and decay when found diluted with N in air.

Since the action is on vegetable or animal matter composed principally of carbon and hydrogen, the products of the oxidation are largely carbon dioxide (CO_2) and water (H_2O).

Note. — Ozone is a more active form of oxygen than ordinary oxygen. The ordinary form of oxygen has two atoms in each molecule, being expressed as O_2, while ozone is expressed O_3. Ozone is formed by the discharge of an electric machine in the presence of moisture; it can be detected by its pungent odor. It is formed in large quantities by lightning flashes. This peculiar form of oxygen is one of the most powerful oxidizing agents known. It is present in pure country air and is absent in the atmosphere in and about large cities. There is probably so much of impurity in the air of the city that the ozone gives up one of its atoms in the oxidizing process and is thus transformed into O_2, or ordinary oxygen. The bleaching of clothes laid out on the grass is probably hastened by the ozone in the air. Putrid meat thrust into a jar of ozone very soon loses its bad odor, because of the activity of this gas.

HYDROGEN (H)

Description and Occurrence. — Hydrogen is the lightest substance known, being one sixteenth as heavy
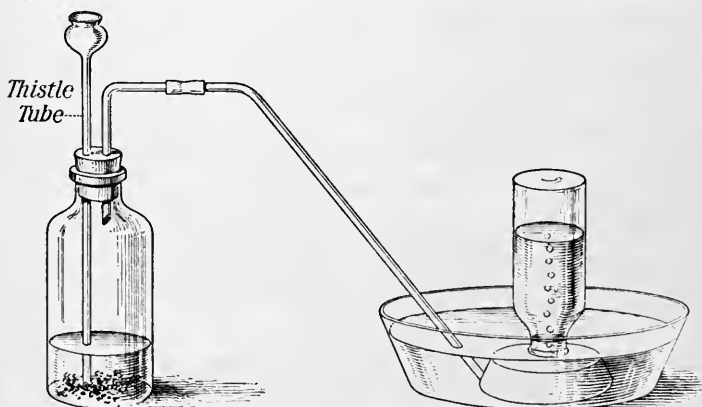

Thistle Tube

FIG. 4. — Preparing Hydrogen.

as O and two twenty-ninths as heavy as air. On account of its lightness H is used for inflating small balloons.

Large balloons are inflated with illuminating gas, which contains much H.

Hydrogen is odorless, colorless, and tasteless. Although it is not found free in any considerable quantities, in compounds it is very abundant. It is present in water (H_2O), in all the oils, and in all vegetable and animal substances.

Preparation. — Fit a bottle with a stopper having two perforations, one for the delivery tube and one for a thistle tube to conduct liquids to the bottom of the bottle. No heat is required. In the bottom of the bottle put a small quantity of chips or filings of zinc. Pour diluted hydrochloric acid in the thistle tube till the zinc is covered with about

FIG. 5. — Collecting Hydrogen by Upward Displacement.

one half inch of it. As soon as action commences, which may be noted as a kind of boiling and the formation of many bubbles, the gas may be collected over water.

Reaction: $Zn + 2\,HCl = ZnCl_2 + H_2$

Notes. — As H is very light, it will escape when the jars are placed in an upright position unless they are covered tight or left inverted. Throw away the first jar of H obtained, as it may have air mixed with it, which makes it explosive. The second jar may be tested by placing a lighted match at the mouth of the jar.

As H is lighter than air, it may be collected by upward displacement. Take the delivery tube out of the water and thrust its open end into a test tube held in an upright position with its mouth held downward. The H will soon drive out the air and may be burned as before.

The H will burn quietly as it escapes, or it may explode with a harmless puff. In either case water is formed ($2 H_2 + O_2 = 2 H_2O$).

Chemical Properties. — Hydrogen will not combine with all other elements. It combines readily with O and has a strong affinity for chlorine (Cl). In direct sunlight H unites with Cl with explosive violence, in diffused light quietly, and in darkness not at all. When the combination takes place, hydrochloric acid (HCl) is formed. Burning H produces one of the hottest flames known.

NITROGEN (N)

Description and Occurrence. — Free nitrogen is a colorless, odorless gas. It is one of the constituents of air, forming four fifths of it. It is very unlike oxygen. O is active, N is inert. N hinders the activity of O. O sustains life, free N has no physiological effect. O combines with most elements, N combines with very few. Nitrogen in combination with other elements is found in niter (saltpeter), from which it gets its name, and other nitrates. It is found also in ammonia, in flesh, in hair, and in all vegetables and grains.
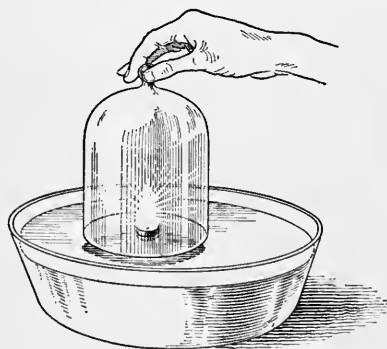

FIG. 6. — Preparing Nitrogen.

Preparation. — The air contains the two elements O and N free, and an easy way to obtain the N is to remove O from the air; this

can be done by causing it to oxidize some substance with which it will readily combine.

The usual method is to place a small piece of phosphorus on a large flat cork, float the cork on water, and cover it with a jar. The phosphorus uniting readily with the oxygen in the jar leaves the N with some fumes of a compound of phosphorus and oxygen. These fumes will soon be absorbed by the water, leaving the N comparatively pure.

Notes. — As the oxygen is combined with phosphorus, water rises and fills the space left vacant — about one fifth of the jar. This shows the volume of O to be about one fifth and N to be about four fifths of the air.

A piece of burning candle may be placed on the cork instead of the phosphorus. The product of the combustion is CO_2. If now the mixture be collected over lime water, the CO_2 will be removed and the N will remain nearly pure.

Chemical Properties. — The chief characteristic of N is its inertness. The difference between O and N in this regard may be shown by placing a jar of O and a jar of N near each other and rapidly passing a lighted candle from one jar to the other. The N will put out or diminish the flame, and the O will relight it from a spark remaining on the wick. This may be repeated a number of times. Although four fifths of the air we take into our lungs is N, we get none of the N that is in our bodies from this source. The N that we obtain comes through the food that we eat.

Plants are surrounded with air that contains the N, but most plants appropriate little or none of the free N. They obtain their supply of N through their roots in the form of nitrates in solution.

Nitric acid, HNO_3. — This is one of the most important and one of the most powerful acids. It was formerly called aqua fortis, meaning strong water, on account of its caustic action. Care should be taken not to get any of this acid on the hands or on the clothing. When pure, nitric acid is colorless, but it is usually slightly tinted with brownish oxides. Put one or two drops in a glass of water, place a drop of the mixture on the tongue and note the sour taste.

It is a powerful oxidizing agent and one of the most corrosive substances known. It colors animal and vegetable tissues containing N (such as silk and skin) yellow and changes some substances that contain no N into highly explosive substances, such as gun cotton and nitroglycerin.

Nitric acid is formed in considerable quantities by the electric discharges in thunder storms. Nitric acid is also formed in the soil under favorable conditions, certain bacterial ferments being active in producing it. This acid combines so readily with minerals in the soil that it exists as acid but a short time.

Note. — HNO_3 is prepared by heating a mixture of sodium nitrate ($NaNO_3$) and sulphuric acid (H_2SO_4). The fumes that arise are conducted into a retort and there condensed by cooling.

$$NaNO_3 + H_2SO_4 = NaHSO_4 + HNO_3.$$
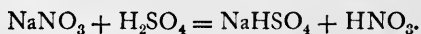
Nature of Acids. — The description given of nitric acid will apply largely to all acids, though they are not all equally powerful, and not all are liquids. All acids contain H. Not every compound, however, that contains H is an acid. Most acids have a sour taste, and everything that has a sour taste is an acid or contains acid. The sour taste of a lemon is due to the

presence of citric acid, that of sour milk to lactic acid, and that of vinegar to acetic acid. Acids will change blue litmus paper to red. This is the most common test for an acid.

There are four very common acids with which students should become familiar:

$$Sulphuric\ acid\ (H_2SO_4)$$
$$Nitric\ acid\ (HNO_3)$$
$$Hydrochloric\ acid\ (HCl)$$
$$Carbonic\ acid\ (H_2CO_3)$$

Note. — Litmus paper is made by staining unsized paper with litmus solution. Litmus is made from certain lichens. A substitute for litmus paper may be made by boiling red cabbage leaves and soaking unsized paper in the liquid. A strong acid will turn any dark-colored vegetable matter red. (A little book of blue litmus may be obtained at any drug store for a few cents.)

Ammonia (NH_3). — Ammonia exists in small quantities in the air and is brought down to the earth in the rain and snow. When we open a bottle of aqua ammonia bought at the drug store, a gas escapes that has a most pungent odor. This gas is ammonia (NH_3). The liquid in the bottle is aqua ammonia. It is water combined with ammonia, and thus charged, it is put up as an article of commerce.

Ammonia is formed in all decaying animal bodies, in manure and urine, and in decaying vegetable matter in the soil. NH_3 may be smelled about manure heaps, in horse stables or cow barns. It escapes very easily into the air and is lost. It is one of the chief fertilizing substances in manure, hence its escape into the air should be prevented as far as possible.

The ammonia of commerce is obtained as a by-

product in the manufacture of illuminating gas in the cities. Ammonia combined with water represents a great class of compounds, called bases, that are the opposite of the acids.

Nature of a Base. — A base is a compound containing O and H, that turns red litmus blue, and neutralizes an acid.

All acids contain H. All bases contain the hydroxyl radical OH. Acids turn blue litmus red, bases turn red litmus blue. Acids and bases mixed together destroy the essential characteristics of each other and form a new substance, called a salt, and water.

An alkali is a base that is soluble in water, combines with fats to form soaps, and has a caustic action on animal and vegetable tissues.

Ammonium hydroxide is a good illustration of an alkali.

Some of the important bases are:

Ammonia (NH_3), when combined with water (NH_4OH) and then called ammonium hydroxide; potassium hydroxide (KOH); (caustic soda) sodium hydrate ($NaOH$); (lime) calcium oxide (CaO) or with water ($CaOH_2$).

Test a small quantity of dilute nitric acid (HNO_3) by dipping in it a strip of blue litmus paper. Note that the blue color is turned to a bright red. This is the acid test. Pour into a dish a few drops of ammonia and water (NH_4OH). Let the part of the litmus paper that has been turned red by the acid touch the ammonia. Note that the red is turned back to the original blue color by the alkali. Pour a few drops of ammonia into the nitric acid and test again with the blue litmus paper. If it still turns the litmus red, continue adding NH_4OH to the acid and testing with litmus till a mix-

ture is obtained that has no effect on the blue litmus. The acid is then said to be *neutralized*. It is also true that the alkali has been *neutralized* by the acid. The reaction may be expressed:

$$\text{Acid} \quad + \quad \text{Base} \quad = \quad \text{Salt} \quad + \quad \text{Water}$$
$$HNO_3 \quad + \quad NH_4OH = NH_4NO_3 \quad + \quad H_2O$$
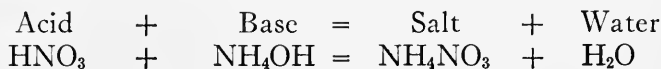
If, now, the water is evaporated, the salt, ammonium nitrate, (NH_4NO_3), will remain as white crystals.

Note. — If by accident acid of any kind gets on the clothes and turns them red in spots, the color may sometimes be restored by touching the spots with ammonia.

Nature of Salts. — Salts affect neither blue nor red litmus; they are produced when acids and bases are combined.

Sodium chloride ($NaCl$), or common salt, is the salt with which we are most acquainted.

By combining the bases listed above with nitric acid the following salts are formed: ammonium nitrate (NH_4NO_3); potassium nitrate (KNO_3); sodium nitrate ($NaNO_3$); calcium nitrate ($Ca(NO_3)_2$). Write all the reactions for the above.

Note. — It may be thought peculiar that NH_4OH is not written NH_5O. NH_4 is called a radical. OH is also a radical. A radical is a combination of elements that hang together so that they act as a single element. Although it would not be wrong to write it NH_5O, it is easier in writing reactions to keep it in the form given. NH_4 unites with OH just as K unites with OH. Other important radicals are:

The nitrate radical, NO_3, as in potassium nitrate, KNO_3.
The sulphate radical, SO_4, as in sulphuric acid, H_2SO_4.
The phosphate radical, PO_4, as in phosphoric acid, H_3PO_4.
The silicate radical, SiO_3, as in silicic acid, H_2SiO_3.
The chlorate radical, ClO_3, as in potassium chlorate, $KClO_3$.

Sulphuric acid, H_2SO_4, uniting with the bases produces the salts called sulphates. Write the reaction for forming the following salts: potassium sulphate (K_2SO_4), sodium sulphate (Na_2SO_4), and calcium sulphate ($CaSO_4$).

Hydrochloric acid (HCl) will produce salts, called chlorides, when combined with bases.

Write reactions and give names for NH_4Cl, KCl, NaCl, and $CaCl_2$.

Note. — The following word endings and prefixes may aid students in understanding some chemical terms:

The ending *ic* means *ordinary* or *common*, as PCl_5 is phosphor*ic* chloride and HNO_3 is nitr*ic* acid.

The ending *ous* means *less*. PCl_3, phosphor*ous* chloride, means *less* of the chlorine than in phosphor*ic* chloride, and HNO_2, nitr*ous* acid, less of the oxygen than in nitr*ic* acid.

The prefix *hydro* means *hydrogen* and *no oxygen*, as in HCl, hydrochloric acid.

The ending *ide* is used for compounds made up of but two elements or one element and a radical, as in NaCl, sodium chloride, and KOH, potassium hydroxide. *Hydro-ic* acids yield salts ending in *ide*, other *ic* acids yield *ate* salts, and *ous* acids yield *ite* salts.

Protein

Crude Protein. — The nitrogenous organic compounds of plant and animal life are very complex, and the terms used in describing them have been very loosely applied. Crude protein is the term used to include all the nitrogenous matter in foods; of these substances the proteins are the most valuable.

Proteins are compounds of nitrogen with carbon, hydrogen, oxygen, and sulphur. The exact formula has not been determined in every case. The proteins contain about 16 per cent of N and less than 2 per cent

of S. The most familiar forms of the proteins are albumins, casein, fibrin, gluten.

Albumins are easily coagulated by heat. The most familiar albumin is that of the white of an egg. It also exists in the blood and tissues of animals, and in grains and vegetables. Being soluble in water, it may be extracted from vegetables and meats by soaking in water. Much valuable food may be lost by improper cooking. Hot water will coagulate the albumin and it will then remain in the article cooked, whereas cold water will dissolve and extract the albumin.

Casein represents a class of proteins found in milk. A similar substance is called vegetable casein which is found in plants and may be extracted from some of them. Casein is not coagulated by heat, but is coagulated by acids and ferments, chief of which for practical purposes is the acid and ferment obtained from the inner surface of a calf's stomach, called rennet. The coagulation of casein, or the making of curd, is one of the necessary steps in the manufacture of cheese.

Fibrin makes up the larger part of the fibrous portion of lean meat or muscle. In its soluble form it is found in the blood.

Gluten forms one of the most important nitrogenous food substances found in grains. It is present in wheat and it is this which forms the sticky part of dough when it is kneaded. A gum of gluten may be easily made by chewing wheat for a few minutes. The saliva dissolves the starch and the gluten remains as a light-colored gum.

Note. — Gluten is made up of two substances, glutenin and gliadin. Gliadin is the substance that sticks together the flour particles, glutenin is a grayish substance that is held together to make up the gluten. The

difference between the soft, or winter, wheats and the hard, or spring, wheats is due to the varying proportion of these substances in the gluten. A larger proportion of gliadin makes a soft wheat.

Alkaloids make up another class of nitrogenous compounds that are sometimes called the *active principles* of plants because of their active effects when taken into the body. Many of the alkaloids are used in medicine and most of them are poisonous. The following are some of the most common alkaloids:

From Peruvian bark . . . . Quinine
From tobacco . . . . Nicotine
From coca leaves . . . . Cocaine
From white poppy pods . . . . . Morphine
From black pepper . . . . Piperine
From nux vomica . . . . Strychnine

⨍ CARBON (C)

Description and Occurrence. — The elements heretofore considered in their uncombined state are in the form of gases. Carbon, however, as found free in nature is a solid. In its free or natural state it may exist as a diamond, which is a crystalline form of carbon, and graphite, which is found in the crystalline and noncrystalline forms.

When combined with oxygen it forms carbon dioxide, CO_2, a constituent of the air on which all vegetable life feeds. All vegetable and animal bodies contain C, and when these bodies are heated with an insufficient supply of O another form of non-crystalline carbon is formed; namely, charcoal. Combined with H, and also free, carbon occurs in coal, petroleum, and the many forms and products of these substances. United

with oxygen and calcium or magnesium, it appears as limestone, marble, and dolomite.

Notes. — Diamonds are usually found in the form of rounded pebbles. These are cut into desirable forms by pressing the stone against a revolving wheel covered with a mixture of diamond dust and oil. Carbon in this form is the hardest known substance except carborundum. This quality, combined with its brilliance and its rarity, makes it the most precious of gems.

Graphite is used in making lead pencils, stove polish, electric light carbons, axle grease, and crucibles. It is often called plumbago.

Charcoal. — Charcoal is made by heating wood with a small supply of O. It is made in large quantities by piling up sticks of wood in a heap around a central flue, covering the wood with earth, leaving a hole at the top for a flue and small holes at the bottom to admit a quantity of O to commence the combustion. After the wood is kindled, the holes at the bottom may be closed so as to regulate the supply of O entering the kiln. When the process is complete, the charcoal is in the form of the sticks that were put in, but its character and its color are considerably different. It is very porous and has the power of absorbing gases to a remarkable degree. Beechwood charcoal has been known to absorb 170 times its own volume of dry ammonia.

It is this property of absorption that gives charcoal its value as a purifier and deodorizer. Oxygen being held in the pores of the charcoal in a condensed form, any offensive gas absorbed by the charcoal is brought into contact with its condensed oxygen, whereupon the impurity is oxidized. This process may be continued for a considerable time. When the charcoal gets full of the impurities, it may be restored to its former condition by reburning.

Carbon Dioxide (CO_2). — This substance is often called carbonic acid gas. It is one of the constituents

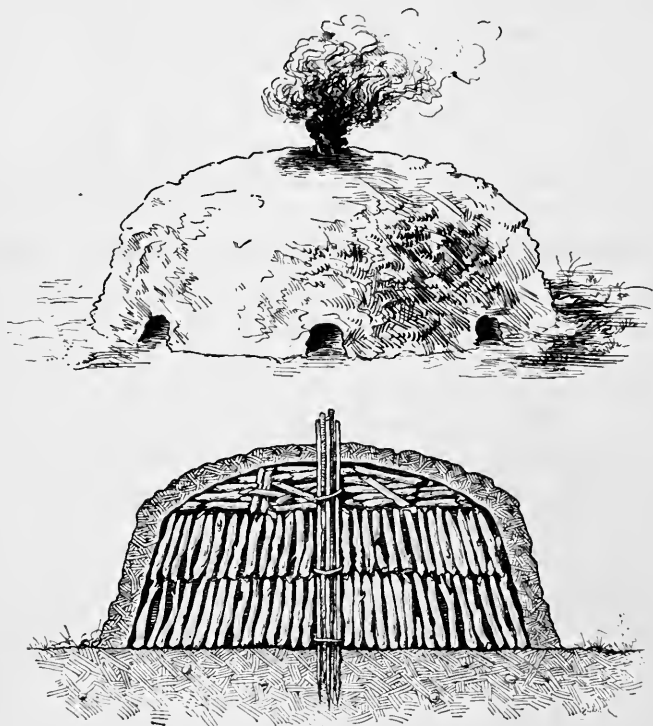Fig. 7. — Making Charcoal.

of air, of which it forms about four parts in ten thousand. It occurs combined in all carbonates, the most abundant of which is limestone ($CaCO_3$). Millions of tons of CO_2 are thrown into the air yearly by the burning of carbonaceous matter, the breathing of animals, by fermentation, and by the decay of animal and vegetable matter. Almost any acid will act on any carbonate

and liberate CO_2. Carbonate of lime ($CaCO_3$) may be treated with HCl to obtain CO_2 for laboratory use. The reaction is:

$$CaCO_3 + 2\ HCl = CaCl_2 + H_2CO_3$$
$$H_2CO_3 \qquad\quad = H_2O + CO_2$$
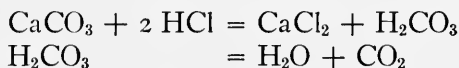
In this case carbonic acid is formed, but is so unstable that it immediately breaks up into H_2O and CO_2. Since CO_2 is heavier than air, it may be collected by pouring as one would a liquid. If care be used, it may be transferred from one vessel to another in this way.

Note. — The gas produced in fermented liquors and that which causes bread to rise is CO_2. Yeast is an active ferment which when mixed with flour and water under proper conditions produces CO_2. This gas makes the bread light by forming little bubbles throughout the mass of the dough till the baking hardens the dough so that it retains the little spaces.

The gas in soda water is CO_2. It gives a sharp, prickly taste to carbonated water and a pungent sensation in the nose as it escapes.

CO_2 is not a supporter of combustion. Test this property by putting a lighted splinter or match into a jar of the gas, and note how quickly it is extinguished.

CO_2 sometimes accumulates at the bottom of a well, a cistern, or a silo. Before going down into such a place, one should lower a lighted lantern or candle. If the light is extinguished, there is sufficient CO_2 present to suffocate any one going into it.

The limewater test is the usual one for CO_2. Pour into a glass or test tube some clear limewater, $Ca(OH)_2$. Through a straw or glass tube blow into the limewater

till it turns a milky white, calcium carbonate having been thus produced by the CO_2 in the breath. The reaction is:

$$Ca(OH)_2 + CO_2 = CaCO_3 + H_2O$$
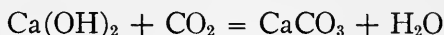
The decomposition of carbonaceous matter in the soil forms CO_2. This uniting with H_2O forms a weak acid, carbonic acid, $CO_2 + H_2O = H_2CO_3$. This weak acid acts on the minerals in the soil and renders the plant food bound up in them available. The minerals dissolved by this acid are much greater than would be dissolved by pure water, and since the formation of carbonic acid is continuous, the amount of mineral matter made available is very great in the aggregate. The carbonic acid combines readily with certain bases to form compounds beneficial to plant growth.

The most important use of CO_2 is its direct use as food for plants. All green vegetation is feeding on the CO_2 and building up carbonaceous tissue. This feeding takes place in the presence of green matter (chlorophyll) in vegetation under the influence of sunlight. CO_2 breaks up; O is thrown out into the air and C is combined with H_2O to make some of the organic compounds, such as starch, sugar, and woody fiber.

The food of man and other animals comes directly or indirectly from plants. Much of the food thus taken is oxidized in the blood and tissues, and CO_2 is formed and again returned to the air. Thus the cycle of changes continues, and the amount of CO_2 in the air is held unchanged in amount.

Humus. — Animal and vegetable matter in soil

partly decayed, or oxidized, is called humus. Organic matter in the soil is not properly called humus till it has passed the most active stage of decomposition and has lost the physical structure of the substances from which it is made. It has a dark color and partakes of many of the properties of charcoal. New soils generally have an abundance of carbonaceous matter, but by constant cropping and failure to add manure or to turn under green crops this carbonaceous matter becomes exhausted. Although it is true that plants cannot take it through their roots, yet the carbonaceous matter mellows the soil, and absorbs and holds ammonia gas so that it may be acted on chemically, and nitrates may be formed that may be taken in by the rootlets as plant food. The presence of carbonaceous matter is of the utmost importance in providing a means of making other plant food available for the use of the plant. It also encourages bacterial growth of certain kinds that are essential in the preparation of plant foods.

Note. — Carbon monoxide (CO) is very poisonous. The presence of CO is shown by the blue flame over a fire of coke or hard coal. It is formed by the red-hot coals taking from CO_2 one of its atoms of O. This gas has a direct poisonous effect when it escapes into a room, often causing death. It is also present in the illuminating gas furnished by cities.

Some Hydrocarbons and Derivatives. — The compounds of hydrogen and carbon without O are called hydrocarbons. The number of such carbohydrates is very great. They exist in nature as the constituents of petroleum, natural gas, and asphalts. They may be formed by the heating of carbon compounds without the free mixture of O, as in the manufacture of charcoal and illuminating gas.

Carbohydrates. — Carbohydrates differ from hydrocarbons in that all of them contain hydrogen and oxygen in the proportion to form water:

Glucose $C_6H_{12}O_6 = 6\,C + 6\,(H_2O)$
Cane sugar $C_{12}H_{22}O_{11} = 12\,C + 11\,(H_2O)$
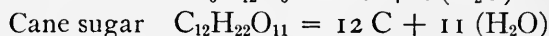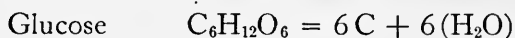
The most familiar carbohydrates are the sugars, cellulose, starch, and gums.

Glucoses ($C_6H_{12}O_6$) are the simplest forms of sugar. They are also called grape sugar and dextrose. They are found in all fruits, in honey, and in the liver. Commercial glucose is made from corn starch in large quantities in the United States and from potato starch in Germany. It is made by boiling the starch with dilute sulphuric acid. The acid is removed by treating with lime and filtering. Glucose in this form is sold under various names, such as *corn sirup, golden drip,* and *silver drip.* If the sirup is evaporated to dryness, crystals are formed that resemble cane sugar, but they have less sweetening power than cane sugar. The solid glucose is sold under the name of grape sugar.

Note. — Many candies and some grades of brown sugar are sometimes made of glucose or grape sugar. The comparatively low price of cane sugar and the strict enforcement of state and national pure food laws have stopped the practice to a great extent.

Sucrose ($C_{12}H_{22}O_{11}$) is the sugar that is meant when the word sugar with no qualifying adjective is used. This well-known form of sugar is found in a great number of fruits, vegetables, nuts, trees, and in honey. The chief sources of commercial sugar are sugar cane and sugar beets. First, the juice is extracted by machinery, and is neutralized with lime. Second, this juice is evaporated till a thick sirup remains.

Third, the sirup is clarified by filters of bone black. The sirup is now clear and colorless. Fourth, the sirup is evaporated. To make the evaporation more complete without changing any of the sugar to glucose, this process is carried on in vacuum pans. This allows boiling to take place at a lower temperature than in the open air. Some sugar crystals are formed, but the product has much sirup still remaining. Fifth, the crystals are separated from the sirup by being rapidly whirled in cone-shaped sieves, called *centrifugals*. The mother liquor not crystallizing is molasses.

Granulated sugar, then, is a pure crystallized carbohydrate commercially produced from sugar cane or from sugar beets. If the crystals are dried in cubical molds, it is called *loaf sugar*.

If the juices after treatment with lime are heated and a portion of the water evaporated to a certain point, a sirup is obtained which when cooled turns into sugar called *brown sugar*.

Maple sugar is a sucrose with a distinctive flavor derived from some of the other ingredients in the sap of the maple tree.

Sugar of Milk, *Lactose*, $C_{12}H_{22}O_{11} + H_2O$. This sugar is found in the milk of all milk-giving animals. It is a by-product in the manufacture of cheese. The casein is separated from the milk by means of rennet. The sugar of milk remains in the whey and may be separated by evaporation and purified by recrystallization. The crystallized product is used as a container for medicines. It is not so sweet as cane sugar. Sugar of milk constitutes about five per cent of cow's milk. The souring of milk is caused by the fermentation of sugar of milk forming lactic acid.

Cellulose $(C_6H_{10}O_5)_n$. The *n* in this formula stands for an indefinite number of multiples of the radical expressed. The molecule may contain twenty or it may contain two hundred times the number of atoms given in the formula. The chemical analysis may show the same elements with the proportions as given, but the substances may be very different in appearance and may vary by the different ways in which these elements come together, as well as in the number of atoms in the molecule.

Cellulose is found in every part of every plant. The coarse wood of all trees and the tender shoots of the most delicate plants contain cellulose. It constitutes the outer wall of vegetable cells and is therefore an essential part of all plants. Cotton, hemp, and flax fibers consist almost entirely of cellulose.

Cellulose may be dissolved in sulphuric or other acid. If, then, the solution is heated under pressure, part of the cellulose is changed into glucose. Thus it is apparent that glucose may be made of sawdust, rags, and paper.

Note. — Paper in its many forms consists largely of cellulose. It may be made from wood, rags, and straw. Whatever substance is used, it is first finely divided or pulverized and boiled in a weak alkali. This pulp mixed with water is poured over a steadily moving wire cloth. The water passes through the cloth, leaving the sheet of pulp, which, gradually drying, is passed over the drying cylinders, and is then finished as desired.

Starch $(C_6H_{10}O_5)_n$ is found in grains of all kinds, and it forms the largest part of the solid matter of many vegetables. Starch is produced in the leaves of all green plants during growth and is deposited and stored in the roots, stems, and seeds or fruits. The starch of com-

merce is obtained from potatoes and from corn.   It is
made up of small grains which,
when seen under the microscope,
show each grain to be made up of
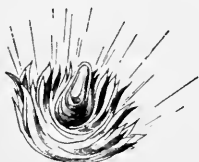concentric rings with the nucleus at

Fig. 8. — Granules of Po-
tato Starch.

one side. These
grains   when
heated in water
nearly to the boil-
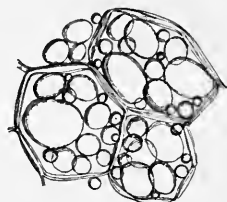ing point form a

Fig. 9. — Starch Gran-
ule Bursting.

pasty mass. This is caused by the
swelling and bursting of the starch
grains. Fine white flour contains about
74 per cent of starch, rice contains about 79 per cent,
and potatoes about 16 per cent.

Note. — The presence of starch in solution may be shown by the
iodine test. Dissolve a few grains of iodine in alcohol. Put into a
glass of water a drop of boiled starch. Pour into this mixture a
few drops of the dissolved iodine. The mixture will be colored blue.
The color will be apparent if only a very small amount of starch is put
into the water.

Boil the colored solution and note that the color disappears. It
reappears on cooling.

Dextrin ($C_6H_{10}O_5$). When heated to about 212°
starch may be changed to a soluble form, known as
dextrin. The chemical composition remains the same
as starch, but the atoms are differently arranged in the
molecule. Dextrin is soluble in cold water and makes
a mucilage. The mucilage on postage stamps is made
largely of dextrin. The starch of the loaf of bread has
been changed into dextrin in the brown crust. The
ease with which toast is digested is due to the same
change in the starch.

Gums. Knowledge of the chemistry of gums is quite limited. They have the same general formula as the dextrins and are products of various trees and plants. The most familiar are gum arabic, wood gum, and gum tragacanth.

Nitrogen Free Extract. — When a chemical analysis of food is made, a portion that has no nitrogen in it, non-nitrogenous, is called nitrogen free extract. It consists largely of the carbohydrates other than cellulose, which is named crude fiber.

Fats

Fats and oils are found in both vegetable and animal bodies. They are produced from starch in plants during the progress of growth. Fat is found in all parts of the plant, but the mature seed has the largest proportion. The seeds of flax, cotton, and corn are particularly rich in fat. During germination the fat in the seed changes back to starch.

The fats and oils are salts; that is, they are made by the union of a base and acid. The base is glycerin $(C_3H_5(OH)_3)$ in its pure state a sweet, colorless, odorless liquid. The character of the fat depends upon the acid that is united with the glycerin. There are four acids that are most common in forming fats: stearic, palmitic, oleic, and butyric.

Notes. — *Stearin* $(C_{57}H_{110}O_6)$ is a fat made by the union of the base glycerin and stearic acid. It is a solid fat and melts at a comparatively high temperature. Most of the solid animal fats, such as beef, mutton, tallow, and lard, are composed largely of stearin.

Palmitin $(C_{57}H_{98}O_6)$ is a solid fat with a slightly lower melting point than stearin. It is a constituent of human fat, butter, and palm oil.

Olein ($C_{57}H_{104}O_6$) at ordinary temperatures is a liquid. Sperm oil and cod liver oil are rich in olein. Fats that are soft or have a tendency to become liquid under normal conditions owe their softness to the presence of olein.

Butyrin is the fat that gives to butter its characteristic taste when fresh. In strong, or rancid, butter some of the butyrin has changed to butyric acid, which produces the unpleasant flavor and odor. By thoroughly washing, this acid may be washed out of the butter, and then by reworking, the butter may be made more palatable. Renovated butter is made by thoroughly washing strong or rancid butter, melting it, blowing hot air throught it, filtering it, and then rechurning it with sweet milk.

Oleomargarine, or butterine, is made largely from stearin. Beef suet or tallow is melted, and a clear yellow oil is obtained. This oil is allowed to become solid and pressure is applied to it, forcing out an oil which, when mixed with lard and cottonseed oil and churned with milk, produces a wholesome food product somewhat resembling butter.

Ether Extract. This is a term used to indicate substances that are dissolved by ether. In food tables when the term ether extract is used it includes all fats. Ether will dissolve fats, oils, gums, resins, and chlorophyll. The largest amount of ether extract of both vegetable and animal matter is fats and oils.

Saponification, or Soap Making. — When an alkali acts upon a fat or oil, a soap is produced. A teaspoonful of ammonia in a glass of water will make a wash for the scalp. When the scalp is rubbed with this alkali, saponification takes place. The oil in the scalp combines with the ammonia, and a soap is formed which works up into a lather in the hair. Caustic soda and potash are the alkalies commonly used to make soap, soft soap being made from caustic potash and hard soap being made from caustic soda. Soft soap

is potassium stearate, oleate, and palmitate; hard soap is sodium stearate, oleate, and palmitate.

The home method of making soft soap is as follows: Fill a barrel with wood ashes. Pour water on the ashes and allow it to percolate through the ashes and to pass out through a hole near the bottom of the barrel into a jar. This liquid is of a dark brown color, called lye. This process may be continued till the ashes have given up nearly all the potash that they contain. Pieces of animal fats, usually wastes of the kitchen, are melted in an iron kettle. After removing the parts that will not melt, the oil is boiled with the lye till the soft soap is formed.

Alcohols

Although there are numerous carbon compounds that are properly called alcohols, there are but two which are of general interest. They are *ethyl alcohol* and *methyl alcohol*.

Ethyl Alcohol (C_2H_5OH). — This is common alcohol, that which is meant by most persons when using the term. It is a clear liquid which burns with great heat. Because of the abundance of H and the small amount of C, it burns without smoke, therefore does not darken articles heated in its flames. Ethyl alcohol is produced by fermentation of sugar. A plant juice containing sugar, that is, grape sugar, or glucose, when exposed to the air loses its sweetness and changes into alcohol and carbon dioxide.

$$\text{Glucose} \qquad \text{Alcohol} \quad \text{Carbon dioxide}$$
$$C_6H_{12}O_6 = 2\,C_2H_5OH + 2\,CO_2$$
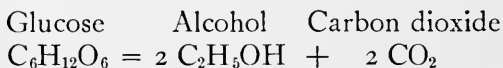
This change is caused by the action of small ferments, called enzymes. The cells which secrete the enzyme

may be in the air, and if they find favorable conditions of temperature and moisture, they will increase rapidly in the substance that is adapted to their life. The action of these organisms on glucose produces alcohol.

Notes. — Enzymes (also called soluble ferments, zymeses, and diastases) are active, organic substances secreted by cells which have the property, under certain conditions, of hastening chemical reactions between certain bodies without entering into the composition of the products which result. Enzymes are secreted in the ptyalin of the saliva, in the gastric juice of the stomach, and the pancreatic juice. These enzymes cause changes in the food we eat, rendering them more easy to assimilate. Enzymes are also secreted by the cells of the yeast plant and cause fermentation to take place.

If a thick solution of glucose is placed in a glass and exposed to the air, no change takes place. Fermentation requires the presence of some enzymes. If then there is introduced into the solution some vegetable matter containing nitrogen, the enzyme-producing organisms have a favorable medium for development, and alcohol is produced. Both the enzymes and the albuminous matter may be introduced directly in the form of yeast. A portion of a yeast cake put into the glucose solution will cause alcoholic fermentation to take place.

There are other ferments adapted for growth in other substances than sugar. The vegetable ferment that causes the souring of milk is called a *lactic ferment*. Another ferment acts upon alcohol and produces vinegar. This is called *acetic ferment*. Butyric fermentation is caused by an organism in butter.

Distillation. — Alcohol is made in large quantities from corn and from potatoes. The starch in the corn and in the potato is changed into glucose by fermentation, and then the glucose is changed into alcohol. A still is necessary for distilling and collecting the alcohol. A mash made of the corn or vegetable from which the alcohol is to be made is allowed to ferment till the alcohol is formed in it. The mash is then

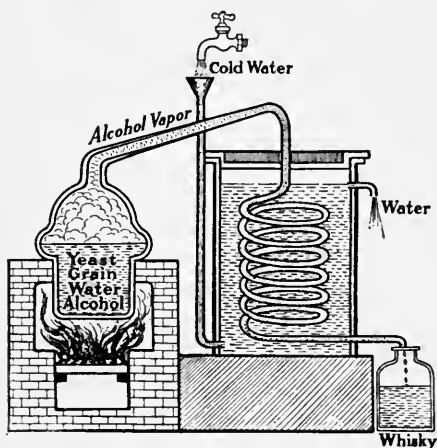placed in a boiler and heat is applied. The heat produces a vapor which is made up of alcohol and water with some other substances. The vapor is conducted through a tube to a condenser. Here the tube is continued in the form of a spiral, called the worm. Cold water is passed through the condenser continuously so that the worm is kept cool. This condenses the vapor passing through it.

FIG. 10. — A Still.
(From Davison's *The Human Body and Health.*)

This product is largely a mixture of alcohol, water, and other alcohols, called *fusel oil.* The water may be partially removed by further distillation.

The water cannot be entirely removed by distillation, but a product containing about 96 per cent of alcohol may be obtained by this process. By other methods all the water may be removed and the product is *absolute alcohol.*

Notes. — Fusel oil, found in distilled liquors, is extremely poisonous.
Proof spirits is a low grade of alcohol that contains just enough alcohol to burn (49 per cent).

Many intoxicating beverages depend upon alcohol for their intoxicating principle. These beverages are merely alcohol with water and a small amount of the

substance of the fruit or grain from which they are made.

Acetic fermentation often follows the alcoholic fermentation. If it is not checked by bottling or cooling, the alcohol is broken up into acetic acid and water.

Alcohol	Oxygen from air		Acetic acid		Water
C_2H_5OH	$+$ O_2	$=$	$HC_2H_3O_2$	$+$	H_2O
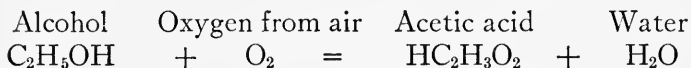
Pure alcohol exposed to the air will not oxidize, but when some nitrogenous substance is added to it the acetic fermentation takes place.

Vinegar consists of water with from about four per cent of acetic acid. It may be made by allowing weak spirits of wine or any other weak alcohol to trickle slowly through a cask filled with beech shavings which have previously been soaked in a strong vinegar. The production of acetic acid is caused by the presence of an enzyme secreted by cells which when collected in masses is called *mother of vinegar*.

This mother covers the shavings in the cask and causes the oxidation of the alcohol. This method is

FIG. 11. — Making Vinegar.

called the *quick method*. If the spirits of wine is placed in a cask with the bung removed to allow the entrance of air, the same result will be produced, but it will take some months to make the change complete.
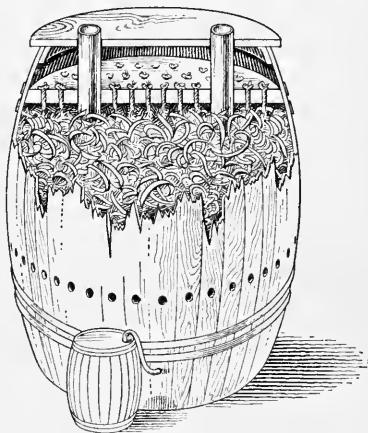
Cider Vinegar. The sugar in the juice of the apple ferments to alcohol, forming *hard cider*, and if the fermentation is allowed to continue, the alcohol is in turn changed to acetic acid and *cider vinegar* is produced.

Vinegar may be made in the same way from maple sirup or from any other liquid that contains sugar.

Methyl Alcohol (CH_3OH). — Methyl alcohol is also called *wood alcohol*, because it is produced by the destructive distillation of wood. It is one of the substances produced when charcoal is made. Methyl alcohol resembles ethyl alcohol in its appearance. It may be used to dissolve gums, for fuel, and for many other purposes for which ethyl alcohol is used. It is a deadly poison.

Denatured Alcohol. — Ethyl alcohol may be made unfit for use in liquors by mixing with it about ten per cent of wood alcohol and pyridine or about one per cent of benzine. This makes a very nauseating mixture called denatured alcohol, which can be used in the arts instead of pure alcohol. The government tax has been taken from denatured alcohol.

Phosphorus (P)

Phosphorus does not occur free in nature. In its manufactured state it is seen in the form of sticks somewhat larger than a lead pencil and two to four inches in length. It is kept in bottles filled with water, for if allowed to remain in the air it unites so readily with O that it is soon consumed. It should never be handled with dry fingers, as it makes a very deep and dangerous burn. It may be removed from the water with iron tweezers. As soon as the air commences to

act on it, a disagreeable odor is produced. The fumes are P_2O_5. P_2O_5 unites readily with H_2O.

Phosphoric pentoxide		Water		Phosphoric acid
P_2O_5	$+$	$2\,H_2O$	$=$	$2\,H_3PO_4$
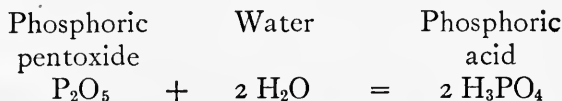
Notes. — Phosphorus may be obtained by treating bones with H_2SO_4 after the animal matter has been burned out of them. This changes the calcium phosphate to calcium superphosphate and calcium sulphate. The sulphate is removed by filtration and the superphosphate is mixed with powdered charcoal, heated and distilled, and the distillate collected under water. The phosphorus is then melted under hot water and run into molds.

Matches owe their inflammability to the presence of the phosphorus in the head of the match. To make the sulphur matches the end of a small piece of wood is stuck in a paste, made of phosphorus, sulphur, and glue, and the whole is coated with glue to protect the phosphorus from the air. To make the cracking matches the paste is made of phosphorus, chlorate of potash, and glue. The heat produced by the friction of the match is sufficient to ignite the phosphorus; this produces heat enough to cause the sulphur or the chlorate of potash to burn, and this, in turn, causes the end of the stick to burst into flame. Safety match boxes have red phosphorus and powdered glass on the sides, and the matches are tipped with sulphide of antimony and chlorate of potash. Unless the match is scratched on the preparation on the match box, it will not ignite.

Phosphates. — The element phosphorus is taken up in considerable quantities by nearly all food-producing plants. It is found in the fruits and in the grains. Although the plant takes the largest amount of P during the early part of its growth, this element is stored up in the fruit or the grain before maturity. If the element is not present in the soil in available forms, the plant dies of starvation.

The element phosphorus is not taken up in its pure form by the plant, but in the form of dissolved mineral matter, called phosphates, which are absorbed by the roots. The most important of these used by the plant is calcium phosphate, or, as it is commonly called, phosphate of lime.

Note. — Phosphates are an essential part of the food for man and other animals. They are not only necessary to bone formation, but are found in all the tissues of the body, the nerve tissues and the brain containing a large percentage. Phosphates are excreted by the kidneys, the quantity excreted seeming to bear a direct ratio to the amount and intensity of brain action.

Calcium Phosphate $(Ca_3(PO_4)_2)$. — There are two principal sources of calcium phosphate, the bones of animals and phosphatic rock. Phosphatic rock deposits are probably the accumulated remains of the bones of prehistoric animals turned into stone; so that it may be said there is but one great source of calcium phosphate, namely, the bones of animals.
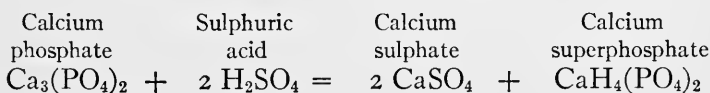
The fresh or green bones of animals have much organic matter in them, and because of this, though the bones are ground fine, the powder does not dissolve readily for the use of the plant. The bones are therefore boiled and steamed to extract all of the animal matter. They are then ground fine and sold as *steamed bone meal*. This contains about 30 per cent of phosphoric acid. In the large packing establishments, where many thousands of animals are killed yearly, the bones accumulate in such quantities that they are economically treated to make phosphate fertilizers.

Mineral phosphates, as they are mined, contain varying amounts of phosphoric acid. That mined in

Quebec and Ontario, called apatite, has about 40 per cent of phosphoric acid, while the beds of phosphatic rock in South Carolina yield 28 per cent, in Florida 3 per cent, and in Tennessee 35 per cent. Large beds of phosphate have been discovered in the western part of the United States, but they have not been mined to any great extent.

Since the grains remove such a large quantity of phosphates from the soil that is not restored by present methods of farming, many soils are becoming unproductive. The beds of phosphate rock will all be needed to restore the phosphates taken out of the soil. Measures are being proposed to prevent the exportation of the products from these beds so that the supply necessary for use in this country may not be exhausted.

Superphosphates. — A chemical analysis of a given soil may show that it contains a large supply of calcium phosphate, and yet this may not be in the right form for the plant to use; that is, it may not be *available*. The phosphoric acid in steamed bone meal is slowly available, and a little of it can be used by the plant as soon as it is applied. Many of the mineral phosphates are so nearly insoluble that their phosphoric acid is *very* slowly available. It is then said to be *unavailable*. On account of this lack of availability of the phosphorus in mineral phosphates, they are often treated with sulphuric acid for the purpose of rendering the phosphoric acid available. The rock so treated is called superphosphate, or acidulated rock.

Calcium phosphate		Sulphuric acid		Calcium sulphate		Calcium superphosphate
$Ca_3(PO_4)_2$	$+$	$2\,H_2SO_4$	$=$	$2\,CaSO_4$	$+$	$CaH_4(PO_4)_2$

In the form of a superphosphate the phosphorus is available, and the treated rock becomes a valuable fertilizer.

The untreated rock, called *floats*, may be acted on by the carbonic acid or the humic acids in the soil and rendered slowly available. If an immediate return of fertility is desired, a superphosphate should be used. Permanent improvement in a soil may be made by use of the mineral phosphates or floats, which become slowly available as plant food, spreading their effect over a number of years.

Reverted phosphoric acid represents a condition of turning back of the superphosphate, or the available phosphoric acid, to the unavailable form. It is still counted as available, though its degree of availability is lessened.

Note. — The conservation of the fertility of the soil is a most serious material problem, and the vital factor in this problem is the supply of phosphorus. The solution of the question of where the supply of phosphorus for future generations is coming from is one which can be delayed but a few years longer, if the fertility of the soil is to be maintained. It has been estimated that there is not enough native phosphorus in the upper seven inches of the average soil of the corn belt to last fifty years, if maximum crops are taken off each year. Long before the expiration of the half century, maximum crops will probably be impossible because of the gradual exhaustion of phosphorus. The visible supply of rock phosphate, at the present rate of use, will not last fifty years. The other commercial source is bone meal, a product made by fertilizing companies and packers by grinding the bones of animals slaughtered for food. Although the supply from this source is slowly increasing, the total output is not adequate to make good the depletion of the soil by continuous harvesting of crops.

Potassium (K) (L. *Kalium*)

Description and Occurrence. — The element potassium is a soft metal with a brilliant bluish white luster. It is one of the lightest of metals and floats on water. Its marked affinity for O leads to the ready decomposition of water when potassium is thrown on it. The liberated H catches fire and the whole burns with a beautiful violet flame. Potassium is not found free in nature, but in its compounds it is very widely distributed. These compounds are found in soils and rocks, forming one of the essential mineral forms of plant food. Plants take potassium salts through their roots, and when they are burned it remains as potassium carbonate in the ashes.
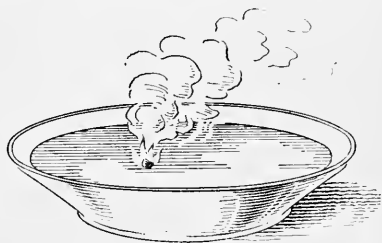

Fig. 12. — Potassium burning on Water.

The metal K is not of great importance, but the salts, potassium carbonate, potassium nitrate, potassium chloride, and potassium sulphate, are of the utmost importance to the farmer.

Note. — On account of its affinity for O, the metal potassium is kept in petroleum or naphtha, which contains no O. The metal should be cut into small pieces about the size of a pea for placing on water. As there is a slight explosion as the last particle is consumed, one should not stand too close to the dish.

Potassium Chloride (KCl), sometimes called muriate of potassium. — This potassium salt, more than any of the other potassium compounds, is used as a fer-

tilizer in the United States. It is the cheapest source of potassium obtained from commercial fertilizers. On account of the chlorine that it contains, it should not be used to a great extent for tobacco, onions, beets, or potatoes.

Potassium Carbonate (K_2CO_3). — This salt is prepared in this country by leaching wood ashes to form potash lye, then evaporating the lye in large pots, whence its name potash. When refined it is called pearl ash. It is a very strong alkali and is used in the manufacture of soft soap. The largest supply is obtained as a by-product in the manufacture of sugar from sugar beets.

All crops are improved by a light application of wood ashes to the soil. Such sources of potassium on the farm should not be wasted nor lie out in piles unprotected. Leached ashes have very little potassium left in them. Besides potash, ashes contain carbonate of lime and phosphoric acid, which give them added value as a fertilizer. Coal ashes have no potassium salts that are available as food for plants and therefore cannot be used as a substitute for wood ashes.

Potassium nitrate (KNO_3), niter or saltpeter, is a white solid usually seen in crystalline form. It is present in most fertile soils and is used in the manufacture of nitric acid and gunpowder. It is an antiseptic compound and is, therefore, often used with common salt (NaCl) for preserving meat.

Note. — Gunpowder is a mixture of pulverized charcoal, pulverized sulphur, and potassium nitrate (KNO_3). Its explosiveness is due to the formation of CO_2 and N in large quantities as soon as ignition takes place. The reaction may be expressed :

$$2\ KNO_3 + S + 3\ C = K_2S + 2\ N + 3\ CO_2$$
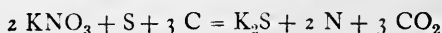
Potassium Sulphate (K_2SO_4). — This is prepared from some of the Stassfurt salts and furnishes a large percentage of potassium in the compound. It is especially valuable as a fertilizer because it can be applied in places where potassium chloride (KCl) cannot, the latter being destructive of vegetable life if applied directly to the plants.

Note. — Vast amounts of potassium salts have been mined in the Stassfurt salt mines in Germany. Many thousand tons of these salts are shipped annually to all parts of the world. The Stassfurt mines were first mined for rock salt and the potassium salts were regarded as troublesome impurities. The great value of these salts was soon found out, and supplying them to the world has become one of the greatest industries of Germany.

Potassium hydroxide (**KOH**), caustic potash, is a white solid usually sold in the form of sticks about the size of a lead pencil. The sticks are kept in closed bottles, as the hydroxide attracts the moisture in the air and CO_2 slowly changes it to K_2CO_3 (potassium carbonate). Potassium hydroxide is one of the strongest alkalies known. It quickly destroys both animal and vegetable substances, and hence should not be touched with bare hands. It unites with grease to form soft soap.

Kainit. Kainit is a low grade of potassium salt mined in Germany. It is used as a fertilizer very extensively. Although it contains but a small amount of potash compared with other potassium fertilizers, it is considered valuable because of its action in rendering available nitrogen compounds in the soil. It consists of potassium sulphate and magnesium chloride.

As it comes from the mines it is mixed with common salt, gypsum (calcium sulphate), potassium chloride, and other minerals.

Note. — Potassium hydroxide is used to destroy the soft horn form· ing on the heads of calves, thus easily and painlessly dehorning them. Wrap a piece of paper about a stick of KOH to protect the hand, moisten one end of the stick, and rub it on the nub of the horn appearing on the head of the calf. Care should be taken that none of the caustic flows down on the skin of the animal. Two applications will effectually prevent the growth of the horn.

Calcium (Ca)

Description and Occurrence. — Calcium is abundant in the ash of all plants and gives to plants vigor of growth and ability to stand climatic changes and drouth. It is a yellowish white, soft metal, not found free in nature. As a metal it is of little importance, but its compounds are widely distributed on the surface of the earth.

Calcium carbonate ($CaCO_3$) is also called carbonate of lime. This important compound makes up the larger part of limestone and of marble; the shells of oysters and other mollusks are composed almost entirely of it, while in the bones of animals and the shells of eggs it enters as an important ingredient. Water charged with CO_2 dissolves calcium carbonate, producing a bicarbonate of lime.

$$CO_2 \ + H_2O \ = H_2CO_3$$
$$CaCO_3 + H_2CO_3 = CaH_2(CO_3)_2$$
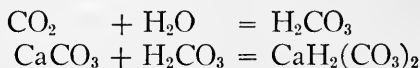
It is this compound with others that makes what is called hard water.

Carbonate of lime is found in ample quantities in

most soils, but some soils do not have enough to supply plants with the lime that they need. In such cases lime may be supplied in the form of ground limestone. Carbonate of lime will correct the acidity of sour soils and will unite with nitric acid to form calcium nitrate, an available form of plant food.

Lime has also a good physical effect on soils. When applied to light, sandy soils, it has a tendency to bind the particles of sand together, while on heavy clay soils it renders them more open and porous and helps to admit air. Although carbonate of lime furnishes an essential plant food, namely calcium, the soil may have an ample supply of this element in other compounds and still need carbonate of lime to improve the physical condition of the soil, to correct its acidity or to aid in rendering available other forms of plant food. To obtain the best results, lime should be applied with manure or other forms of plant food. The old couplet,

> " Lime without manure
> Makes the father rich and the children poor,"

expresses a truth that should be heeded.

Calcium oxide (**CaO**), quicklime, is made by heating limestone ($CaCO_3$) in a kiln. A kiln is often built from rough stones in the side of a hill. The limestone is then piled in such a way in the kiln as to make a place for the fire, but piled so loosely that the heat may pass up among the pieces of limestone. The process of burning the lime requires several days. CO_2 is driven off by the heat, leaving CaO, or quicklime.

Quicklime may serve as a fertilizer the same as $CaCO_3$,

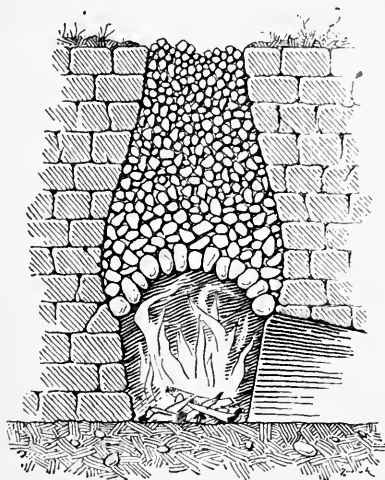but it must be used very sparingly and never put on the land after the latter has been seeded.


FIG. 13. — A Lime Kiln.

If CaO is exposed to the air, it absorbs moisture and CO_2 and falls down in a powder called *air-slacked* lime. This is a mixture of calcium carbonate and calcium hydroxide $(Ca(OH)_2)$. Air-slacked lime may also be used as a fertilizer, but should not be applied directly to plants.

Calcium hydroxide $(Ca(OH)_2)$, caustic lime, slacked lime, is prepared by adding water to quicklime.

$$CaO + H_2O = Ca(OH)_2$$
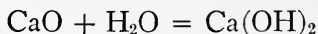
It is a white powder, strongly alkaline. It is only slightly soluble in water, the dilute solution obtained being called limewater. When the particles of hydroxide are mixed with the limewater, milk of lime is produced, and when part of the water is evaporated, the resultant is called cream of lime.

Slacked lime mixed with water and sand makes the mortar used for building purposes. The mortar hardens in air, forming $CaCO_3$, but will not harden in water. The burning of limestone that contains more than 15 per cent of clay yields hydraulic lime, or cement. A mortar made of cement will harden under water as well as in air.

Calcium Sulphate ($CaSO_4$). — This compound is found in the mineral form, anhydrous, but a much more familiar form is its combination, with H_2O, called gypsum. When gypsum is heated to about 250° F., it loses a portion of the water bound up in its crystals, called *water of crystallization*, and when ground into a powder, is called plaster of Paris. Gypsum, either burned or unburned, is called plaster or land plaster, and has been used extensively as a fertilizer. As such it has much the same effect as lime, making the potassium compounds more soluble. It may be used to great advantage as an absorber of ammonia on the floors of stables and under the roosts in poultry houses.

Note. — Plaster of Paris is a white powder used in making the putty coat, or outside coat, of plaster on walls, in making casts of various objects, and as a cement for sticking glass and metal, sucn as the brass rings to the top of lamps. When plaster of Paris is mixed to a paste with water, it sets with increase of volume. This characteristic makes it particularly valuable in making casts and taking copies of medallions.

Magnesium (Mg)

Description and Occurrence. — Magnesium is a metal of a silver-white appearance which is easily tarnished in moist air. It is prepared for commerce either as a ribbon or as a powder. The ribbon, when burned, produces a very bright light, having much the same effect as sunlight. In the powdered form it is used to make the flash light for taking photographs in darkened rooms.

Magnesium is an essential element for the growth of plants, but the compounds of magnesium found in the soil are everywhere so plentiful that plants never suffer for the want of it.

Magnesium sulphate ($MgSO_4$), Epsom salts, found in many mineral waters, is a very common drug used in medical practice.

Magnesium carbonate ($MgCO_3$) is frequently used as an adulterant of face powder. This is the magnesia of commerce or magnesia alba. It is often combined with calcium carbonate and then is called dolomite or dolomitic limestone. The soft crayon used in schools is made by mixing magnesia with a fine clay to give it strength.

Sulphur (S)

Description and Occurrence. — Sulphur exists in various forms as an element. It may be melted and run into molds, making the common form sold in the stores as *brimstone*. It may be vaporized and collected on the cool walls of the chamber containing the vapor. It then appears as a yellow powder called flour of sulphur. If boiled and poured slowly into cold water, it becomes dark colored and non-crystalline, or amorphous. In this form it has much of the elasticity of rubber.

Large quantities of sulphur are mined on the island of Sicily, from which source has come in the past most of the world's supply. In recent years, Louisiana and Texas have supplied very much of the sulphur for this country.
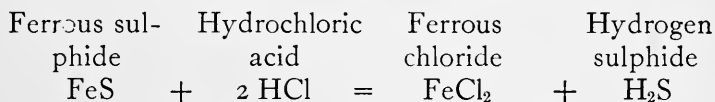
Sulphur is found in compounds in nearly all plants and animals. The color of the hair is probably due to some organic compound of S. The sulphides of the common metals, lead (PbS), zinc (ZnS), iron (FeS_2), and copper (CuS), are combinations with sulphur. FeS_2 is a low grade of iron known as iron pyrites. It is

sometimes mistaken for gold, and is therefore called *fool's gold*.

Some Compounds of S. — Hydrogen sulphide (H_2S), sulphuretted hydrogen, is a gas of a disagreeable odor. This substance is produced in the decay of vegetables and animal matter and gives its most characteristic odor to rotten eggs. It is present in most sulphur springs.

H_2S and other sulphides act on most metals and tarnish them. Silver shows its effects quite noticeably. If a rubber band is snapped around a silver dollar and allowed to remain for a time, a black streak will appear on the coin. This streak is caused by the sulphur in the rubber uniting with the silver, thus producing silver sulphide. This action of sulphur may be seen on silver spoons used to dish boiled onions. Mustard and the yolks of eggs also have a tarnishing effect on silverware.

The action of H_2S on metals makes it one of the most important reagents for use in the laboratory. It is made from the metal sulphides by adding an acid.

Ferrous sulphide		Hydrochloric acid		Ferrous chloride		Hydrogen sulphide
FeS	+	2 HCl	=	FeCl$_2$	+	H$_2$S

The gas is poisonous, and when mixed with air is explosive; hence it should not be made where the gas will enter the lungs or be allowed to escape into a room where there is fire.

Note. — Sulphur is found about 100 feet below the surface in Louisiana. A four-inch pipe is driven down to the bed of nearly pure S. Another pipe leads superheated steam to the S, which is thus melted and then forced by air pressure to the surface through the

first pipe. Here it is allowed to solidify, then broken up into lumps for shipment.

Carbon disulphide (CS_2) is produced by passing sulphur vapor over glowing coke or charcoal. It is a clear liquid, with a pleasant odor when pure, but when kept for a time, especially if water is present in the vessel, it forms products which have an extremely disagreeable odor. Its vapor is very inflammable, hence it should be handled with care. It will dissolve rubber and many other vegetable gums. It is used in mending rubber and making rubber cement. Its vapor being poisonous is used in destroying insects and vermin in rooms that can be closed tightly and left unoccupied.

Sulphur dioxide (SO_2) is a colorless gas having a suffocating odor. It is used for bleaching and is a powerful antiseptic. It was formerly much used for disinfecting rooms where contagious diseases had been present. It is easily produced by burning S in the room. If the room be kept filled with the gas for some time, the disease germs are killed.

Sulphuric acid (H_2SO_4), oil of vitriol, is one of the most important acids used by the chemist. It is a heavy, oily liquid without color when pure. The commercial acid is colored with impurities given it in the process of manufacture.

H_2SO_4 has a strong affinity for water. It will absorb moisture from the air and increase its own bulk. For that reason it should be kept in closely stoppered bottles. It chars wood that is placed in it and will convert a lump of sugar into charcoal. This action is caused by its taking H_2O from the wood or the sugar and leaving simply C. The commercial product is made in large quantities in the process of ob-

taining zinc white from its ore, zinc blend, ZnS. It involves forming SO_2, which, uniting with water vapor,

$$H_2O + SO_2 = H_2SO_3$$

produces sulphurous acid, H_2SO_3. Adding one atom of O produces sulphuric acid. This oxidation is produced in lead-lined chambers by the aid of nitric acid. The process is complicated, but it is given fully in all the standard encyclopedias.

A later and more simple method of manufacture of H_2SO_4 is called the *contact* process. It depends on the fact that certain finely divided metals, more particularly platinum, have the power of hastening some chemical reactions. By this process SO_2 is made to pass through platinized asbestos, during which process it takes O and becomes SO_3. The reaction is

$$2\ SO_2 + O_2 = 2\ SO_3$$
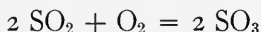
Sulphur trioxide (SO_3) combines directly with H_2O to make H_2SO_4.

Iron (Fe)

Description and Occurrence. — Iron is the most important of all the metals, but is seldom found free in nature. In its pure state it is of little consequence. The iron that is manufactured into machinery, hardware, and building material is a combination of iron and carbon. The proportion of carbon in the combination determines the quality of the metal and the use to which it may be applied. Wrought iron has less than two tenths per cent of carbon and cannot be tempered by sudden cooling, while steel has from two tenths per cent to about two per cent of carbon and may be tempered by sudden cooling. The hardness of the steel

increases with the proportion of carbon that it contains. Iron containing more than about two per cent of carbon is cast iron.

The iron ores as mined are usually in one of two forms, the hematite (Fe_2O_3) having a deep red color of the appearance of red clay, and the magnetite, or magnetic iron ore (Fe_3O_4), which is black in color.

Various iron compounds are found in the ashes of plants, in the blood of animals, in spring, river, and ocean waters and in all soils.

Iron is necessary as a plant food, but only a very small amount is required. There is always a sufficient quantity present in the soil. Iron is an aid in the production of the green coloring matter chlorophyll, without which the plant cannot grow.

Iron Oxides. — Iron unites with O in different proportions forming oxides of iron. The various colored brick are made out of clay containing oxides of iron, the colors being developed by burning the clay. The basis of red paint, red ochres, used for barns and other farm buildings is iron oxide. The rusting of iron may be prevented by covering the metal with a coating of paint, varnish, or metal. Sheet iron is covered with a coating of tin to make our tin ware. A coating of zinc deposited on iron makes galvanized iron.

Ferrous Sulphate ($FeSO_4$), sulphate of iron, copperas, green vitriol. — This compound is used more extensively than any of the other iron salts, being employed in the arts and somewhat as a disinfectant. It has been found to be effective as a destroyer of wild mustard, dandelion, and other noxious weeds when dissolved in water and used as a spray when the parts are tender.

Note. — Copper sulphate, or blue vitriol, has very much the same general effects as iron sulphate. It is also used as a disinfectant and a germicide. Because of its power to destroy plant diseases, it is used in Bordeaux mixture as a spray.

To make Bordeaux mixture. In a wooden vessel containing ten gallons of water hang a coarse sack containing two pounds of copper sulphate ($CuSO_4$) so that it is just below the surface. In another wooden vessel slack two pounds of quicklime

FIG. 14. — Making Bordeaux Mixture.

(CaO) by adding small quantities of water till it has the consistency of cream, then adding enough water to make five gallons. When the copper sulphate has all dissolved and the milk of lime has been prepared, strain the milk of lime through a coarse cloth into the copper sulphate solution. Mix thoroughly and apply with a spray pump.
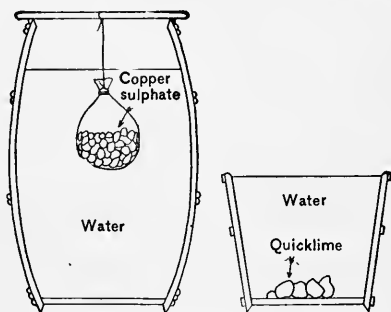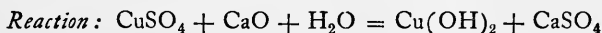
Reaction: $CuSO_4 + CaO + H_2O = Cu(OH)_2 + CaSO_4$

Hydroxide of copper ($Cu(OH)_2$) is the active agent which makes the mixture a fungicide or germicide.

CHLORINE (Cl)

Description and Occurrence. — This is a yellowish green gas with so suffocating an odor that a small quantity of it in the air produces violent coughing. It does not occur free in nature and is not a plant food. Its presence in common salt ($NaCl$) gives it a very extensive distribution throughout the world.

Chlorine has a strong attraction for most of the elements, but more especially for H. This attraction for H enables it to break up many organic molecules

containing this element. In the presence of moisture it breaks up and destroys the molecules of coloring matter of dye stuffs, thus acting as an effective bleaching agent. This is due to the action of O which is set free from water by Cl.

In direct sunlight Cl decomposes water according to the following:

$$2 H_2O + 2 Cl_2 = 4 HCl + O_2$$
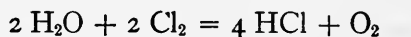
Hydrochloric acid (HCl) is one of the most important and one of the strongest acids known. The pure acid is a gas. When absorbed by water, it makes the hydrochloric acid in the form that is used most frequently, called muriatic acid. The acid is made by heating common salt with sulphuric acid.

Salt		Sulphuric acid		Sodium sulphate		Hydrochloric acid
$2 NaCl$	$+$	H_2SO_4	$=$	Na_2SO_4	$+$	$2 HCl$
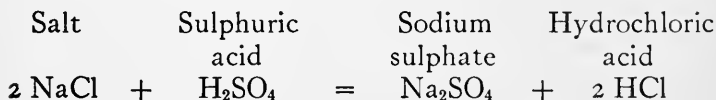
HCl dissolves many metals and forms chlorides. When it is mixed with nitric acid, 3 volumes of HCl to 1 volume of HNO_3, it makes *aqua regia* (royal water), which dissolves the " king of metals," gold. Platinum is also dissolved in a warm mixture of these acids. HCl is found in the human stomach and aids digestion. It is used in the arts to a very great extent and is of great value to the chemist.

Bleaching Powder, chloride of lime. — As usually sold in cans, this is a mixed salt of hypochlorus and hydrochloric acids. Cl may be easily set free by adding a small quantity of acid or by exposure in the open air, under which condition it will escape slowly. This

mixture is used for disinfecting purposes and for bleaching colored cloth.

Sodium (Na)

Description and Occurrence. — Sodium is a metal very much like potassium in appearance and properties. It is not found free in nature and as an element it is not of very great importance, but the compounds of sodium are of the greatest importance to mankind. The principal one of these compounds is common salt ($NaCl$).

Sodium Chloride ($NaCl$), common salt. — This mineral compound is very necessary to human and other animal life. It is widely distributed throughout the world. Sea water contains two and seven tenths per cent of salt, and many springs and wells have the salt in solution. It is also found in solid form in large beds in parts of Europe and the United States.

The salt of commerce is obtained by evaporating the sea water or the water of salt springs and wells or by mining that found in beds. If the water containing salt is evaporated rapidly, the salt forms in small crystals and a very fine table salt is produced; if the evaporation is slower, the larger crystals form and coarse salt, or rock salt, is produced.

$NaCl$ is used in preserving meats and in destroying weeds. It has been used as a fertilizer, but it has no value as a plant food.

Sodium Nitrate ($NaNO_3$), Chile saltpeter. — This compound is a very important one to the agriculturist, for the nitrogen which it contains is an essential plant food. The price of nitrogen in all fertilizers is based on the price of Chile saltpeter. This compound at-

tracts moisture from the air and is readily soluble in water. As a fertilizer it is especially valuable in giving to plants a quick start and for promoting a luxuriant stem and leaf growth.

Sodium Carbonate (Na_2CO_3), sal soda, washing soda. — This compound is ordinarily spoken of as *soda*. It is used in making soap and in the manufacture of glass. It takes the form of crystals when combined with H_2O. If the H_2O be driven off by heat, there remains a white powder which is pure Na_2CO_3.

Acid Sodium Carbonate ($HNaCO_3$), bicarbonate of soda, baking soda. — This compound is also sometimes called "soda." When treated with an acid it effervesces, releasing CO_2. Children sometimes make "home-made soda water" by mixing this soda with vinegar. Its chief use is in the manufacture of baking powder. Baking powders are made by combining sodium bicarbonate with some acid salt. When water is added, the reaction takes place and CO_2 is formed. The salt is usually acid potassium tartrate (cream of tartar) ($KHC_4H_4O_6$), or acid phosphate. To prevent reaction taking place through the absorption of moisture from the air, some substance like starch is added to the baking powder to keep it as dry as possible.

Sodium Hydroxide ($NaOH$), caustic soda, is a white, brittle solid which dissolves in water with the production of considerable heat. It is a very strong alkali. It is used in various industrial processes, resembling KOH in its action, but is less powerful. An impure variety of sodium hydroxide is sold in cans as "concentrated lye."

Note. — Borax is sodium biborate. It is found in nature in several lakes in Asia and in the western part of the United States. The

largest source of borax is from deposits left in dried-up lakes in California. Borax is used in cleaning, in soldering, and as an antiseptic.

ALUMINIUM (Al)

Description and Occurrence. — The metal aluminium is not found free in nature, but is prepared by passing an electric current through a bath of melted cryolite in which aluminium oxide is dissolved. It is a remarkably light metal, very tenacious and ductile, and takes a bright polish. It is used for cooking utensils and because of the fact that it does not form poisonous compounds with foods it is particularly well adapted for such purposes. It is used also to increase the hardness and strength of brass and other metals. Aluminium is not an essential element of plant food, though it is found in most plants in small quantities.

Aluminium Oxide (Al_2O_3), alumina. — This compound is widely distributed, occurring in ruby, sapphire, and corundum. Its crystals are very hard, so that they are sometimes used as substitutes for the diamond in cutting glass and in abrading hard substances. Emery is an impure variety of alumina. The ruby and sapphire are pure aluminium oxide tinted with a trace of some other mineral.

Feldspar is a double silicate of alumina and an alkali (K, Na) or an alkaline earth (Ca) or both. The feldspars form a large part of the great rock masses of the earth. When they are decomposed by weathering the carbonates of the alkalies and alkaline earths are formed, together with clay ($H_4Al_2Si_2O_9$). Thus potassium carbonate becomes available for the use of plants, while clay beds are formed of the clay through the action of

flowing water. The various colors are due to the presence of iron oxides.

Silicon (Si)

Silicon does not occur free in nature, but its compounds are very abundant; alone it makes up about one fourth of the crust of the earth. Silicon is not an important plant food, the popular notion that it serves to give stiffness to the straw of some of the cereal plants being an error.

Silica (SiO_2) is the most common compound of silicon. It occurs in the form of sandstone, quartz, and quartz sand. Quartz is crystallized SiO_2. It often has some coloring matter in it, which gives us the rose quartz, the smoky quartz, and the amethyst. The opal is uncrystallized silica combined with variable amounts of water; flint, agate, and jasper are imperfectly crystallized silica.

Glass is made by melting together quartz sand, carbonate or sulphate of soda or potash, and limestone or lead. CO_2 is driven off in the process, arising through the molten mass in bubbles. The mass is kept in liquid form while the bubbles are being formed. A very clear glass is made by keeping the liquid hot for some time, freeing it from bubbles and refining it.

Water glass is made by melting together fine sand, silica, and sodium carbonate, forming sodium silicate (Na_2SiO_3). It is soluble in water, and when it dries it leaves a transparent coating on substances over which it is spread. It is used extensively as a filler in the manufacture of artificial stone. A solution of one part water glass and nine parts of water makes one

of the best preservatives for eggs. Fresh eggs immersed in the solution will keep for six months and longer without spoiling.

Note. — Glass has no definite melting point as many solids have.

If a piece of glass is heated in a flame, it first becomes soft enough to bend, then it may be pulled out into a fine thread, and then on continued application of heat, it turns to a liquid. Likewise, when it is cooled from the liquid state, it goes through all the stages of change back to the solid state. Crystalline substances usually have definite melting points. Substances such as glass that have no definite melting point are called *amorphous*.

CHAPTER II

SOILS AND FERTILIZERS

Soil

Soil is chiefly decomposed and disintegrated or crumbled up rock. The main decomposing and disintegrating agencies are air, rain, ice, and winds. These agencies are aided by heat and chemical action. The *topsoil* extends only a few inches below the surface of the ground, but the *subsoil* underneath it varies in depth from a few feet to a hundred or more feet.

Kinds of Soil as to Mechanical Composition. — A soil made up of very fine particles, so fine that the separate particles can be distinguished only by the help of a microscope, is called a *clay* soil; a soil made up of particles in the form of grains is called *sandy* soil. A clay soil is usually sticky when wet, does not disintegrate readily on drying, and is hard to work, while a sandy soil permits moisture to pass off readily and is not sticky. *Silt* is soil made up of particles intermediate in fineness between sand and clay.

There is no so-called clay soil that does not contain some granular particles. The ordinary soils as we find them are mixtures of clay, sand, silt, and humus. This may be readily seen by putting a small quantity of ordinary soil in a bottle partly filled with water and shaking it thoroughly. When it is allowed to stand the coarser

granular particles settle at the bottom very quickly, the finer granular particles, or silt, settle next, and after a few hours the finest particles, or the clay, will be found on top of the other deposits.

A *loam* soil is a mixture of sand, clay, and silt in about equal proportions with *humus*, or partly decayed vegetable and animal substances. We may have a clay loam or a sandy loam, according as the one or the other kind of particles predominates. *All productive soils contain more or less humus.*

A limy, or *calcareous*, soil may come from the breaking up of limestone. Like clay it is sticky when wet, but crumbles easily when dry.

As to Deposition.—The action on rocks of the various agencies mentioned above is called weathering. As a result of slow weathering, soils are formed and sometimes remain in the place of formation. Such soils are called *sedentary*. Sedentary soils may also be formed by the accumulation of organic matter, peat or humus, as in swamps and marshes.

Water, ice, and wind sometimes carry soils to great distances from the place of *formation*. Such are called *transported* soils.

The Amazon, the Nile, and the Mississippi, annually swollen by spring rains, sweep to the seas, scattering soil over their adjoining lowlands and depositing large amounts at their mouths in the form of deltas. Every rill and creek and river duplicates the work of these large rivers in a degree proportionate to its size and velocity of flow. Glaciers, those " frozen streams moving slowly, but irresistibly onwards, down well-defined valleys, grinding and pulverizing the rock masses detached by the force and weight of

their onslaught,"[1] have covered desolate and rugged rocky wastes with rich soil. These two active agencies in the formation and transportation of soils — streams and glaciers — produce soils varying in character and hence in name. *Alluvial* soil is due to the action of streams, and *drift* soil is a result of glacial action.

Alluvial Soils. — These soils will naturally be formed of layers, or strata, because the moving water, carrying as it does both coarse and fine particles, will deposit both, the heavier, coarser particles being deposited first. Successive years will repeat this process, hence a soil will be formed of alternate strata of coarse and fine soil, varying in depth, being more shallow in the source regions of the stream and gradually increasing in depth towards the mouths. Such soils are commonly fertile, being made up principally of the finest particles of soil of the basin because they are moved the most easily by the running water. The surface of these soils is naturally smooth and level.

Drift Soils. — Drift soils are made up of stones with a greater or less amount of fine material. There are few strata in these soils, but the depth varies as greatly as does that of alluvial soils. Because of the varying nature of the surface over which the glacier has moved, the surface of the drift soil formed is hilly and usually contains many stones.

If the glacier has moved over and ground up limestone in its progress, the drift soil made is commonly productive, but if the main rock ground up has been sandstone, there is little fertility in the resulting soil.

[1] Stockbridge.

Note. — Many thousand years ago the northern part of North America was covered by a great accumulation of ice and snow, called an ice sheet. The period of the formation of this large glacier is called the Glacial Period. At that time conditions were favorable for the accumulation of a great depth of ice and snow. The pressure became so great at the point of greatest depth that the ice was forced out at the bottom as a vast stream. It extended south as far as the central part of the United States. Such great force had this ice stream in its motion that it planed off large areas of rock, plowed up

FIG. 15. — Map showing the Area of North America covered by Ice in the Glacial Period.

(Salisbury. Geological Survey of New Jersey.)

hills of clay, gravel, and bowlders, and transported the mixture hundreds of miles from its source. When the climate changed and the ice melted, the transported material was left in places in the form of lines of hills called *moraines*, and in other places the surface was left comparatively level, forming rolling prairies.

Moisture in Soils. — The soil is the great storehouse of moisture. Through this conservation of water which the plant needs to hold its food in solution, the

earth is clothed with living verdure. Generally standing water is found in the soil in large quantites, either deep in the ground, or, more rarely, near the surface. This is called *ground*, or *hydrostatic*, water. When found near the surface, ground water must be drained off in order that vegetation may grow, because the presence of so much water excludes the air from the roots of the plant. When ground water exists at a moderate depth, from three to four feet, it is helpful to the plant, as it furnishes necessary moisture to the soil above without excluding the air.

The water that is most helpful to plant life is that which surrounds each particle of soil in a thin layer, or film. This is called *capillary* water. It does not fill all the spaces between the particles and thus does not shut out the necessary air, as does ground water. Capillary water passes freely from particle to particle, always from the more moist to the less moist, and thus to the root tips, by a process which is known as capillary action, or capillarity, — the same process which causes the whole of a linen towel to become wet although only a small corner rests in water, or which causes the oil to rise in a wick.

In dry weather capillarity will draw the ground water up to the roots of plants and thus furnish necessary moisture. Soils never become so dry that heating to a temperature of 212° F. will not show the presence of some moisture. This is known to the scientist as *hygroscopic* water. It is absorbed from the air, as is shown by the fact that the heated soil, when cold, will regain the weight lost by heating. Hygroscopic water clings to the surface of the soil particles, but is not capable of movement as is capillary water.

In the order of their importance to the agriculturist, capillary water ranks first, ground water second, and hygroscopic water last.

Capacity of Soils for Water. — It is evident that a given soil can hold enough water to fill all the spaces between its particles. Experiments have shown that a cubic foot of coarse sand, completely saturated, will hold about one third of a cubic foot of water, while the same bulk of rich humus soil will hold about two thirds of a cubic foot. Other soils will range between these two extremes. But as saturation, or the complete filling of the spaces between the particles, prevents the air from penetrating the soil, the question of importance to the farmer is, not how much water the different kinds of soil can hold, but what are their different capacities for capillary water, or how much water will they hold when all the free water is allowed to drain out.

As capillary water clings to the surface of soil particles, it is plain that the greater the number of particles, the greater will be the extent of surface to be covered with water. In other words, the finer the particles, the greater the power of the soil to hold capillary water. An understanding of this will enable us to see that coarse sand will retain but little capillary water, while a clay loam, rich in humus, will retain a large amount. Obviously, the desirable soil for growing crops, other things being equal, is one that will retain a large amount of capillary water with a subsoil that holds the ground water near enough to the surface to be made available for replacing the loss by plant use and evaporation.

Amount of Water needed by Plants. — It requires an enormous quantity of water to mature a crop. Various estimates have been made of the exact amount

of water needed to produce a pound of dry matter of the different grains, the figures showing that oats require about five hundred pounds and corn about two hundred seventy-seven pounds. The other grains use amounts somewhere between these two. This water, having accomplished its work of bringing plant food to the leaves, is by them passed off into the air. The soil also loses moisture by direct evaporation from its surface, especially during dry, hot, windy weather; hence the supply of water to the soil must replace the losses through the plants and through evaporation if vegetation is to thrive. It is estimated that each ton of dry crop material on an acre requires four inches of water. If, then, five tons of hay are to be produced from an acre, a rainfall of twenty inches, or its equivalent, must be provided.

Conservation of Soil Water. — To reduce the loss of soil water by evaporation, or, in other words, to conserve the moisture already in the soil, is a necessity in regions where at least twenty inches of water does not fall annually, and it is also of great benefit to the growing crop, even where the rainfall is greater than twenty inches. The most effective agent in this conservation is cultivation. This breaks up the soil at the surface and hastens evaporation there, but the dry soil above, through which capillarity acts very slowly, serves to keep the soil moist below and thus the roots are kept supplied with moisture. When the next rain comes, the loose surface soil will allow the water to percolate freely through it to the soil below, for gravity tends to draw free water downward. Breaking up the surface of the soil for the purpose of conserving the moisture is called forming a dirt mulch, or a dust

mulch. Loose straw or any other coarse mulch will also prevent surface evaporation.

Oversupply of Water in the Soil. — The growth of vegetation is retarded by too much water as well as by an insufficient quantity, for, as stated on page 72, an oversupply of water, by filling all the spaces between the particles, will exclude the air, which is as necessary to the life of the plant as is water, and is also necessary to the microscopic vegetable life of the soil, a life that is very beneficial to plant growth.

Too much water will reduce the temperature of the soil, and thus hinder growth.

Another harmful effect is the failure of roots to strike deep into overwet soil, for the plant has little chance for life if the topsoil later becomes dry.

Soil that is too moist cannot be cultivated as it should be, and thus weeds have free growth, and every weed grown deprives a useful plant of food.

Effects of Cultivation on Soil. — Cultivation, or tillage, is the breaking up or crumbling of the soil by means of the plow or other implement, either before or after seeding. There are five beneficial effects of cultivation :

1. It crumbles and mellows the soil.

2. It causes more rapid and greater formation of soluble plant food.

3. It lessens evaporation of soil water.

4. It kills weeds.

5. It makes possible better aëration of the soil.

(1) When the soil is thoroughly crumbled, roots can find their way through it with ease; thus tillage will help to form an extensive root system for crops.

(2) This stirring and breaking up of the soil allows

the roots to come in contact with a greater number of new soil particles, and thus a much larger surface is open to the action of the root hairs. As a consequence of this, a greater supply of plant food is rendered available.

(3) Forming a dirt mulch by cultivation and thus decreasing the evaporation of soil water has already been discussed. It is equally true that evaporation at the surface will be increased by tillage, but then little of this water would be available to the roots, and the formation of the dust mulch will conserve the moisture that is deeper in the soil, that is, near the roots.

(4) Weeds are harmful because they take for their own sustenance what more useful plants require. They are greedy eaters and hard drinkers. Cultivation at the right times uproots and destroys these, and thus saves the nourishment and moisture in the soil for the growing plants.

(5) The beneficial effects of aëration, or admitting air to the soil, have been referred to before, but not explained. The oxygen of the air combines with the carbon of decaying vegetable matter in the soil forming carbonic acid, which is a powerful solvent of some of the compounds of the soil. The breaking up of some of these compounds makes possible the formation of other more soluble compounds, and thus contributes directly to plant growth.

Note. — Microscopic plants abound in the soil. They are called bacteria. They need air for growth. These bacteria are beneficial in that they cause decay of plant and animal bodies in the soil and thus increase the supply of humus. They are useful in forming soluble nitrates from the various insoluble nitrogen compounds in the soil, and thus render available an important plant food. Tillage, by supplying more air to the soil, promotes the growth and work of these organisms.

Tillage Implements. — The spade, the hoe, and the rake are the principal tillage implements for small tracts or small garden plots, but for the farm or the large garden, implements worked otherwise than by hand are used. Horses and oxen have furnished the power for farm tillage for many centuries, but now these animals are often superseded by steam or gas engines.

The Plow. — One of the most ancient of farm implements is the plow. At first a crooked stick drawn by a slave or by cattle, it has developed into the perfectly formed steel plow often pulled in groups or gangs by large steam or gas engines. The plow as we ordinarily think of it is the moldboard plow. There are many types of this plow, depending on the special use to which the plow is placed. The general purpose
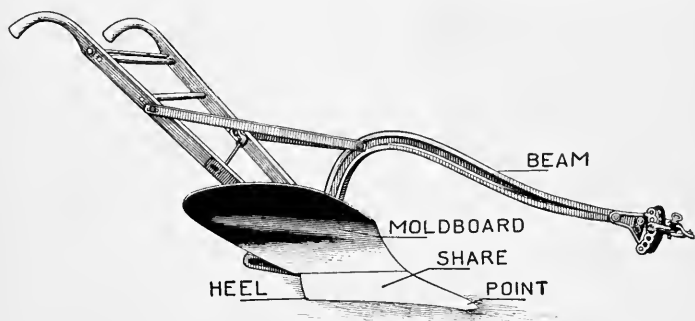
FIG. 16. — General Purpose Plow.[1]

plow which is shown here might be used for all kinds of work if other forms were not available.

The breaking plow has a much longer moldboard

[1] The part of the plow on the other side of the share receiving the pressure when the furrow is turned is called the *landside*. It is not shown in the illustration.

that turns the sod over without crumbling it, while the stubble plow has a steeper and shorter moldboard that breaks up the soil and throws it over in a crumbled mass.
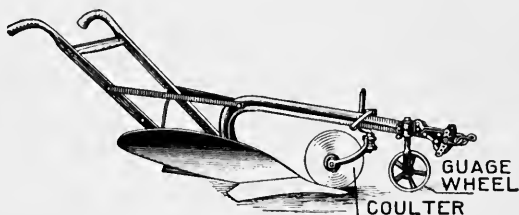
FIG. 17. — Breaking Plow.

Some object to the moldboard plow because the cutting edge and the heel of the plow slide along over the bottom of the furrow and smooth or plaster down the moist earth so that it is more difficult for moisture
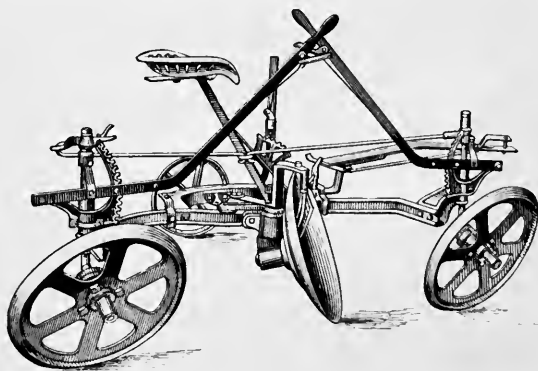

FIG. 18. — Disk Plow.

to get from the subsoil to the plowed surface. This action is avoided in the disk plows that have come into use within the past few years.

The disk plow cuts the soil, pushes it over, and

crumbles it. It may be used where the soil is too hard
or too sticky for
the successful use
of the moldboard
type.

FIG. 19. — Subsoil Plow.

The subsoil plow
is intended to fol-
low after the regu-
lar plow and to
loosen the subsoil in the bottom of the furrow. The
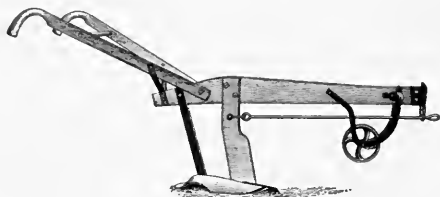
FIG. 20. — Deep Tillage Machine.

subsoil may con-
tain a large amount
of plant food, but
it is usually not
immediately avail-
able for the plant.
If it were thrown
on top, it might
require some time
before the air and
the sun could act
on it and make
available its food
material. The
subsoil plow
loosens the soil
and aërates it
without checking
plant growth by
throwing the soil
on top.

There are some deep tillage machines on the mar-
ket now in response to a demand of deeper tillage.

One of the most successful of these machines consists of two disks, one lower than the other and running in different lines. The first cuts a slice of surface and turns it into the deep furrow at its right. The second disk running deeper throws the under portion over and
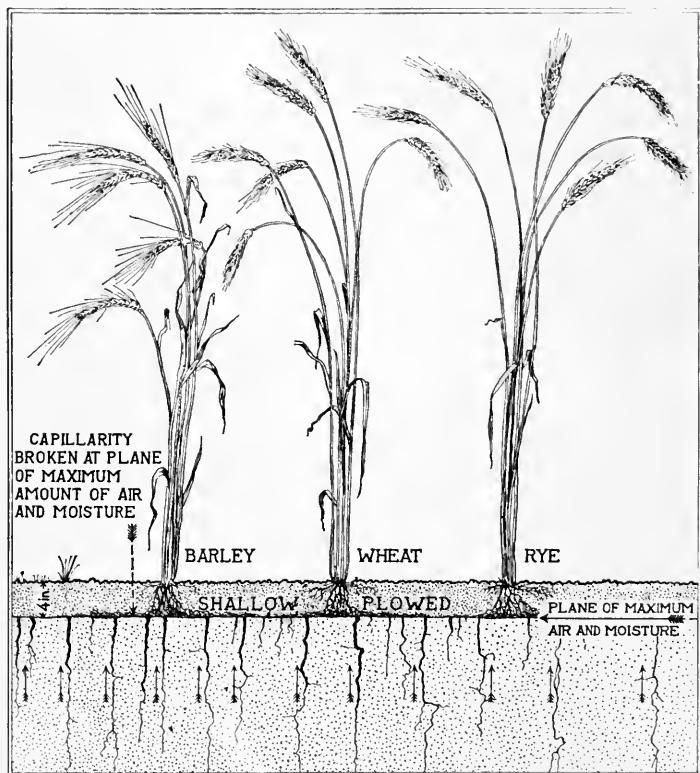
FIG. 21. — Shallow Plowing for Cereals.

against the furrow turned by the first disk, both turning and pulverizing the soil. All trash and surface weeds are thus effectually buried.

Depth of Plowing. — How deep one should plow depends on so many conditions that it is impossible to answer the question directly. The locality, the character of the soil, the amount of moisture in the soil and the amount that may be expected during the growing season, and the crop to be raised are all factors that should be carefully considered in answering the question. The tendency at present is toward deeper plowing, but deep tillage is not the best for all conditions.

In general it may be said that that depth of plowing is best which furnishes the plant during its growth with the greatest amount of air and moisture. The subsoil is usually moist, and it conveys the ground water to the topsoil. If the topsoil is plowed to such a depth that the roots of the plant can spread out on the moist soil
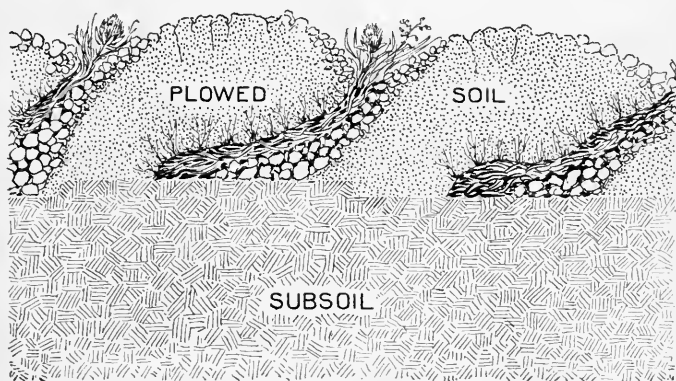
FIG. 22. — Furrow as the Plow leaves it.

immediately under the plowed surface, then the roots will get both the moisture and the air in the loosened and crumbled plowed soil.

The cereals and grasses are shallow feeding plants.

These plants, then, are often best served by shallow plowing — a depth of from three to six inches being sufficient. The corn plant, on the other hand, has a more extensive and deeper system of roots and thrives better on plowing not less than eight inches in depth. For the alfalfa plant, which has a long tap root, the plowing need not be limited as to depth.

Connection with Subsoil. — Whatever the depth of planting determined on as best, the plowed surface

Fig. 23. — Roller.

should be brought into close contact with the subsoil so that capillarity which was broken by the plowing may be reëstablished. The sod or the trash that is turned under often keeps the plowed soil from coming in contact with the undersoil. The plowed surface then soon dries out and crop raising is almost an impos-
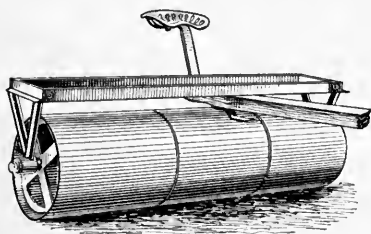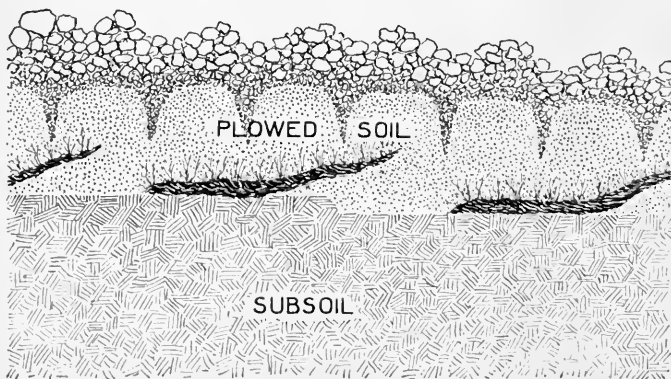

PLOWED SOIL

SUBSOIL

Fig. 24. — Soil as the Packer leaves it.

sibility. To press the plowed soil down hard against the subsoil so that it may get its moisture from the subsoil, many farmers have used the heavy roller successfully. The roller also crushes the clods on the surface,
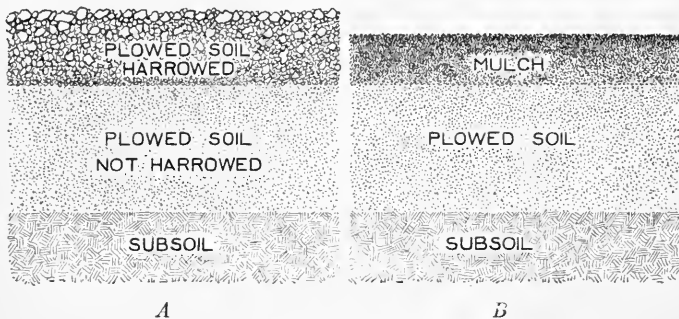

FIG. 25. — *A*, Soil as left by the Harrow; *B* the Same Soil packed by Rain.

so that evaporation takes place rapidly and much soil moisture is lost unless the surface be harrowed to pre-
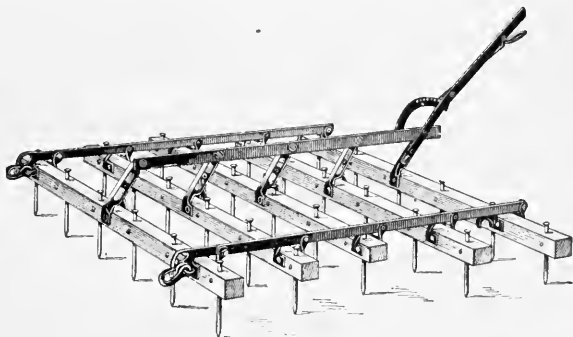

FIG. 26. — Harrow.

vent it. If the surface is very cloddy, the heavy roller may be a necessity.

Another implement has been invented, called a sub-

surface packer, which accomplishes all that the roller accomplishes in packing the soil without destroying the crumbly condition of the surface.   (See Figure 35.)

The Harrow. — The harrow should follow the plow as soon as possible.   It is better to harrow land after plowing before the surface has dried.   When the soil
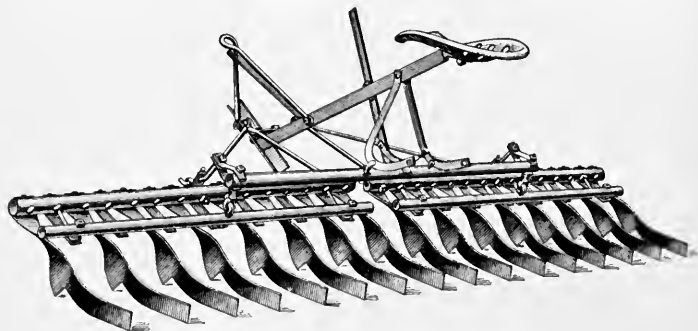

FIG. 27. — Acme Harrow.

is freshly turned over, the harrow can pulverize it more easily and prevent the formation of large clods. Some attach the harrow behind the sulky or driving gang plow and perform both operations at once.   The harrow should be used after a heavy packing rain, even though the seed bed may have been thoroughly prepared.   A rain storm packs and settles the tilled soil, which on drying forms a crust that must be broken up to form a soil mulch and prevent the evaporation of soil moisture.

The spike-toothed harrow is the most common form of harrow, and some farmers have no other kind.   It is used for fining the surface, breaking up clods, and leveling the surface.

The spikes may be driven through a wooden frame,

or they may be placed in an iron frame. A lever is usually attached so that the spikes or teeth may be held vertically, or they may be made to slant at any desired angle backward. This regulates the depth to which the spikes enter the earth.

A curved knife-toothed harrow, also called the

FIG. 28. — Spring-tooth Harrow.

Acme harrow, cuts and pulverizes the soil and is known as a pulverizer.

The spring-tooth harrow also pulverizes and cultivates the topsoil. It is often used in stony ground, or ground in which stumps and roots of trees abound. When the tooth catches on an obstruction, it springs back and releases itself.

FIG. 29. — Disk Harrow.

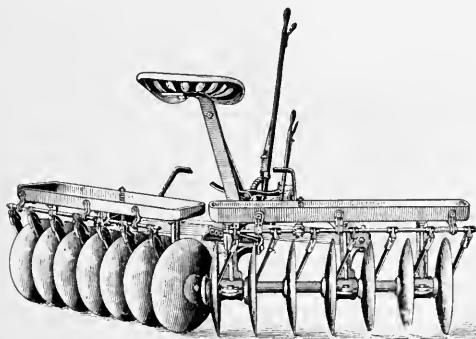The disk harrow is a very effective implement for pulverizing and loosening up the ground. The disks cut the clods, and mix and push to one side the topsoil. The two sets of disks are set at an angle, both sets pushing the soil away from the center. This usually

leaves the field in an uneven condition. It is a common practice in disking to lap over one half the distance each time so that the ground may be left practically level.

The disk harrow is a good weed exterminator and is often used instead of the plow when shallow tillage is desired, as when oats follow corn in rotation.

Other forms of disk harrows having special uses are the cutaway harrow and the spading harrow.

FIG. 30. — Opening a Ditch with a Plow.

DRAINAGE

Land is never in perfect condition unless well drained; that is to say, unless all the water that falls on it or flows over it can soak down to the minimum depth needed for the development of growing crops and then find vent, either through a naturally porous soil or by artificial channels. The housewife makes a practical application of this principle when she puts her house plants in a flower pot which has a hole in the bottom. Without this

vent for the water to pass off after the soil is saturated, the plant would not thrive, for, as we know, excess of moisture is fatal to the growth of the plant.

Methods of Drainage. — Probably the most commonly used artificial method of draining is the surface ditch, sometimes called open drainage, in contrast to the closed drainage, or tiling system. The first seems the more

FARM OF
Aug. Samuelson
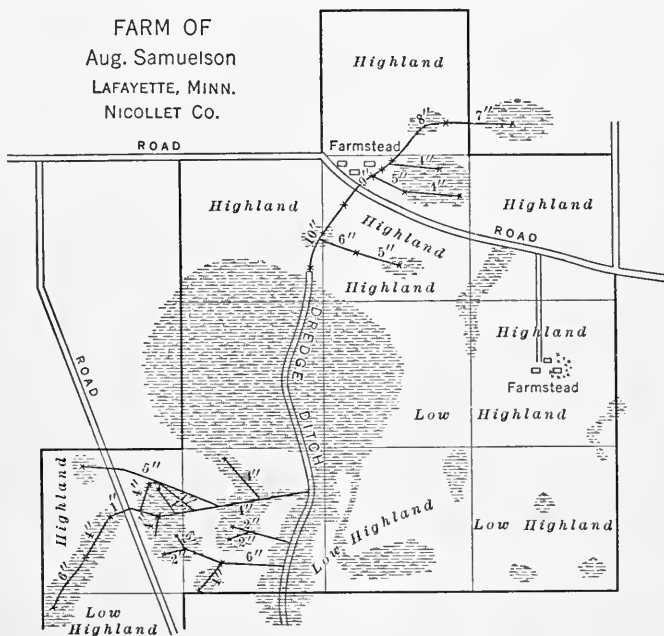LAFAYETTE, MINN.
NICOLLET CO.

FIG. 31. — Drainage Plan of a Farm.

economical because its first cost is cheaper, but it is usually more expensive in the end. The cost of digging a trench is less than that of laying tile, but when once properly laid, tiles last for years and do not fill up, while ditches demand labor each year to keep them in

good condition. Then, too, tiling, being laid underground, is out of the way of tillage implements and does not necessitate the waste of any land.

The depth to which tile should be laid depends upon the character of the soil, compact soil requiring deeper drainage than loose soil. Tile from three to six inches in diameter, laid from three to four feet deep and ninety feet apart will, under ordinary conditions, remove the surplus water from an area of eighty acres.

Open ditches are often constructed either entirely or partly with the aid of a plow and a scraper. The plow is used first to make as deep a furrow as possible and to loosen the earth, then the scraper is used to clean out
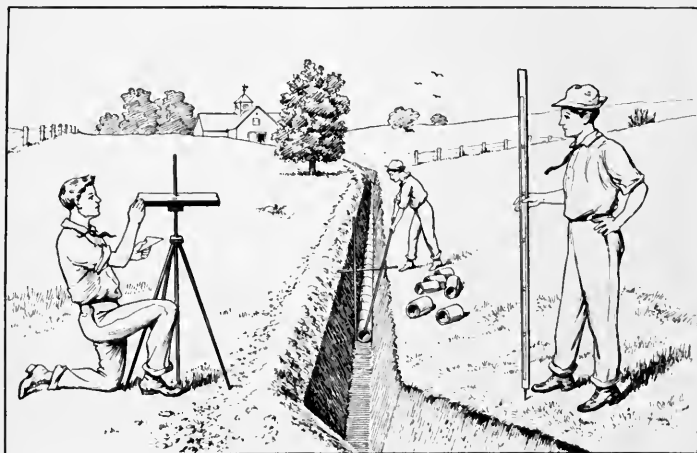

FIG. 32. — Surveying for a Line of Drain Tile with a Home-made Level.

the loose earth. Ditch-digging machines propelled by horses or by a steam or a gas engine are used in localities where much draining is necessary. Closed ditches for tile are commonly dug by ditchers with long-handled

shovels and spades. The ditches are made just wide enough to work in.

As it is necessary for the ditch to be dug so that the tile laid in it shall have a uniform slant or fall from the highest point to be drained to the outlet, it is essential that a careful survey of the land be first made by one who understands drainage engineering if the fall be very slight. If there is a considerable fall, a farmer who can use a level can do sufficiently accurate work for practical purposes.

He maps out the location of the drains and, by means of an instrument called a level, determines at what depth the ditch must be dug over its entire course. If this work is not accurately done, or if his directions are not carefully followed by the ditch diggers, the tile may become clogged up and thus be rendered useless.

After the tiles are laid in the bottom of the ditch, fitted end to end as closely as possible, the ditch is filled in with dirt, usually with a scraper and a team of horses.

Note. — Some may be puzzled to know how the water gets into the tile. The tile is not like a long pipe to take water in at one end and discharge it at the other. It rather serves as a means of directing
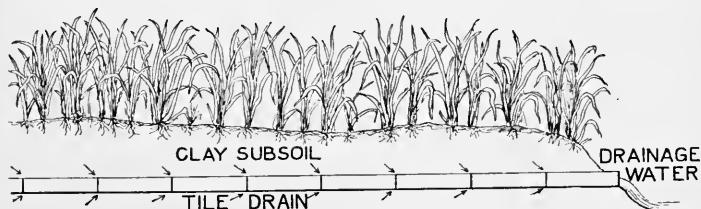

FIG. 33. — Water seeps in at the Joints.

the flow of water in the soil through which it is laid. Water finds this passageway through the fact that the tiles placed end to end are not fitted water-tight. The water seeps in at these slight openings, and

having a course with uniform fall to the outlet, it passes on till discharged. The upper end of the tiling system is not open. The outlet is the end that must be kept open and free from obstruction.

IRRIGATION

In the United States, as well as in other countries, are vast tracts of land where rain seldom falls. There are other large tracts where rain falls during certain portions of the year, but not in sufficient quantities to make them productive. (In fact in very few portions of our country is there moisture enough in every season to insure the maximum crops.) From the Atlantic seaboard to the Rocky Mountains the amount of water precipitated annually gradually decreases, the extreme western portion of this area being arid or semi-arid in character, because of lack of moisture. The last half century has seen the unproductiveness of nature supplemented by man's work, in that a way has been found to supply the needed water to these arid wastes. The process by which water is supplied, other than by natural means, is called *irrigation*.

Sources of Water Supply. — Water for this purpose is often obtained from wells, ponds, lakes, and springs. Sewage from cities is sometimes used on farms lying near, but most of the water used comes from streams. When there is any likelihood that the stream from which water is taken will dry up during the season when water is needed, reservoirs are built so that a greater part of the winter rainfall may be stored.

Uses of Irrigation. — The water applied by irrigation may be useful to the plant in two ways: First, it may be of direct benefit in dissolving and carrying into the plant the various foods found in the soil particles.

Second, when underdrainage has been provided for, either naturally or artificially, irrigation may be useful in removing from the soil the excess of mineral salts (usually termed alkalies), when such are present. Such excess is often found in the arid regions and in lands which were once covered by the sea, such as reclaimed sea marshes.

Soils that are not apparently alkaline naturally have often become so after they have been irrigated for some time without good underdrainage. How this is brought about may be shown by using in the last experiment a can which will not leak at the bottom, and supplying water from the top, being careful not to add too much water at one time.

Note. — The best water for irrigation purposes is that which carries a large amount of plant food, either in solution or suspension, and is of a temperature sufficiently high not to check the growth of vegetation. Rivers whose waters are muddy are often the best for irrigation supply, because the muddiness indicates a large amount of fine silt, which will enrich the soil it is spread over, especially if that soil is a sandy one.

Suggestive Experiments. — (*a*) To show how inland soils may become alkaline, mix a little soda with some wet, fine sandy loam or clay. Place it in a box and let the top dry, but keep the bottom moist. Observe the gradual accumulation of soda on the surface.

The soda, corresponding to the plant foods scattered throughout the soil, is taken into solution by the water as it rises through the soil by capillarity and is left on the top as this water evaporates at the surface.

(*b*) That irrigation in connection with underdrainage may be useful in removing this excess of salts from the soil may be shown as follows: Prepare an alkali soil by mixing potash or soda with dry, sandy soil. Test it with blue litmus paper to see if it is sufficiently alkaline to change the color. Place this soil in a tin can having holes

in the bottom through which the water may find vent. Set the can in a dish, pour water on the soil from the top, and test that which drains through with the litmus paper.

Methods of Irrigation. — Various approved methods of applying water by irrigation are in use in different regions, but those most used are *sprinkling*, *flooding*, *furrowing*, and *tiling*.

Sprinkling. — Of the four methods named, sprinkling most nearly resembles the means by which nature furnishes water to growing plants. In spite of this fact, sprinkling is the poorest of the methods named. To apply a sufficient amount of water at one time by this method requires a very slow application, for, if applied too rapidly, the ground, if it is not sandy, becomes packed and hardened. In this condition sufficient air, which the plant needs, cannot get through the soil and the penetration of the roots is also difficult. There is also very rapid evaporation from the surface unless the soil is stirred soon after sprinkling. This results in great waste of water and renders a second application necessary in a short time. If practiced in a region where there is no rainfall through the summer, it must be repeated often and a sufficient amount given to saturate the soil to a considerable depth; otherwise, the plant will develop a shallow root system and will be largely dependent upon water thus applied all through the growing season.

Flooding. — By this method water is spread over the field in as even a sheet as possible. It can be used only where an abundance of water is available and where the land to be irrigated is naturally quite level or can be made so. As in the case of sprinkling, there will be rapid evaporation unless the surface of the soil is

stirred soon after the water is applied. A great disadvantage in this method is the great length of time necessary to apply water in sufficient amount. This is necessarily so because of the fact that the air in the soil prevents, after a little, the rapid penetration of the water, as the increasing weight of the water above prevents the escape of the air in that direction.

Furrowing. — This method is the one most commonly used in the western part of the United States. Small furrows are dug through the land, the depth and dis-
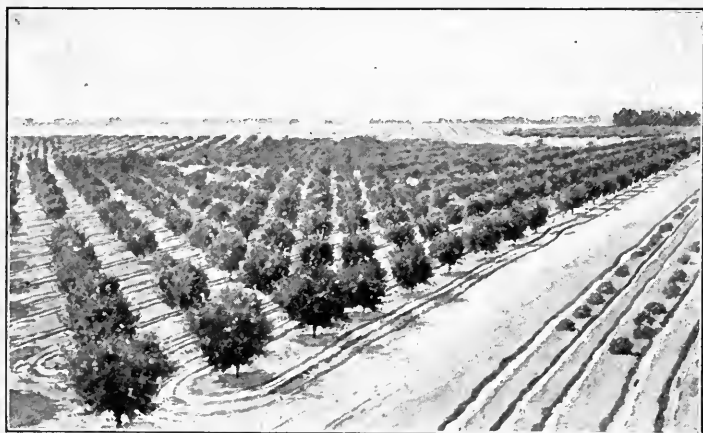

FIG. 34. — Irrigation by Furrows.

tance apart varying with the soil. The more porous soils require a greater number of furrows than clay or silt. The furrows must slant a little, but not enough to make a rapid flow of water or there will be washing.

One of the chief advantages of this method lies in the fact that the water can soak into the soil so that the lower strata become so thoroughly saturated that a deep

rooting system is developed. By this method water reaches the surface of the ground only by capillarity, hence the soil does not become so packed as to exclude the air and hinder root penetration. The furrows should usually be run three to eight feet apart, depending, as stated above, on the texture of the soil and the consequent readiness with which the water penetrates it. This point may easily be determined by experiment before the furrows are laid out.

After the water has been shut off from the furrows and the surface has become dry enough, the furrows should be filled again to prevent rapid evaporation. Losses due to this cause often amount to as much as 50 per cent of the water applied.

Suggestive Experiment. — To illustrate how irrigating furrows moisten the soil laterally, bore a hole in the middle of one side of a box near the bottom and plug it up. Fill the box nearly full of dry, finely crumbled soil. Make a shallow groove, or trench, across the middle of the soil. Slowly pour water into it until the soil at the bottom of the box is damp. This can be ascertained by removing the plug and thrusting a small stick into the hole. Remove a layer of two or three inches of soil near the trench and notice how far from the trench the water has extended by capillary action. Continue removing layers of two or three inches, and notice the difference in lateral extent of moisture at different depths.

Tiling or Subirrigation. — What is considered by some experts to be the climax of scientific irrigation and at the same time the most economical method, is the laying of porous tile pipe under the ground. Some writers call this *subirrigation*. The principle is the opposite of that applied in drainage in that the pores and joints of the pipes give out sufficient water to supply the plant life above them. This plan is considered practicable

in supplying moisture for fruit trees, vegetables, berries, and almost every other kind of product, the advantage being that the water carried by the pipes is discharged directly below the roots of the plants instead of on the surface of the soil. Less water is required because there is no loss by evaporation, but the expense of laying the pipe is great. If the lines of tiles can be laid so that they open out of one ditch and can be readily filled by turning the water into the ditch, the labor cost of irrigation will be kept at a minimum.

DRY FARMING

In the semi-arid regions of the western part of the United States, where the rainfall for the entire year is not sufficient for maturing a crop, a system of cultivating known as *dry farming* is being practiced. It should not be inferred from the name that by this system plants will subsist on smaller quantities of water than in other cases. The system consists in carefully conserving the

FIG. 35. — Subsurface Packer.

moisture that falls during the entire year by summer tillage. During this year the land is not sowed to crops,

but is so treated as to permit of a very small amount of evaporation. The surface is constantly kept loose, being tilled after each rain of any considerable amount. A dirt mulch is thus formed which reduces evaporation to a minimum, and by the use of a subsurface packer capillary action is stimulated so that moisture is brought up from the subsoil to the seeds or roots of the plants. After the crop is planted, the soil is kept loose at the surface until the crop is matured. The moisture conserved through one year by this system is often sufficient for the maturing of crops through the next year. A farmer in the arid region having a 320-acre farm would, then, have 160 acres in crop each year and 160 acres lying fallow, that is, unused by a crop, but tilled during the summer. The system is often called the Campbell system, after its originator.

The principles of dry farming might be put to good use in both arid regions and those where there is a good winter rainfall. In the former areas one application of water would be enough for the entire season. In areas having a winter rainfall the moisture might be so conserved that irrigation would be unnecessary.

Amount of Water needed in Irrigation. — Some authorities claim that fifty thousand gallons an acre are necessary to mature a farm crop by irrigation, but so much depends upon the character of the soil and the subsoil, and also upon the climate and the crop to be raised, that it is difficult to give any accurate estimates. If the climate is humid, less water will be required than in a dry climate. It is better to apply a moderate amount at intervals of several days than to put too much on at a time.

Reservoirs. — As the flow of water in streams is at some seasons of the year overabundant for irrigating purposes and at other times there is a scarcity, dams and reservoirs are built to hold back and save the water for a
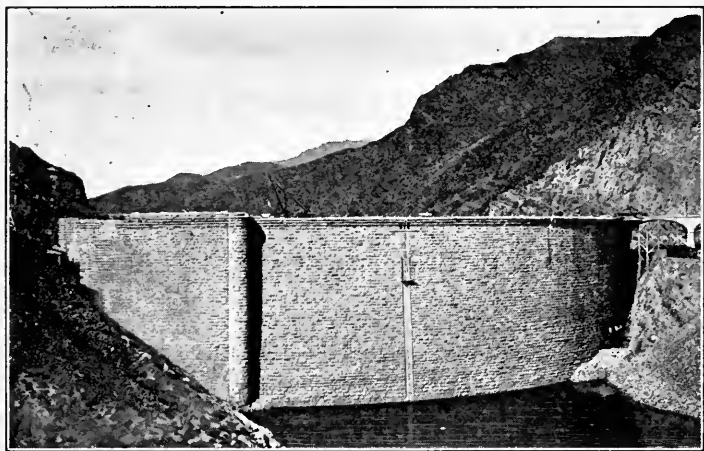

FIG. 36. — Storage Reservoir.

time of drought. The United States government is helping in this work on a large scale by building large storage reservoirs in the West. By this means thousands of acres of desert land have been reclaimed and many more will be as the work progresses. In more humid regions the damming of a small creek or river might save the farmers of the vicinity much loss from drought. The Wisconsin Experiment Station has done more than this. Water was pumped from a depth of about twenty-five feet by burning coal at five dollars a ton and the added expense has been more than met by the increased yield of crops.

Limitation to the Use of Irrigation. — All surface

systems of irrigation interfere somewhat with the use of farm machinery, and the initial cost of any system is considerable, as is the labor cost of working it. These last two objections have prevented the installation of the system in regions which are already fairly productive, and restricted its use largely to areas which but for irrigation would be arid wastes. In spite of cost, however, the increased yield from its use, with fairly fertile as well as barren lands, is so great that it will repay the expenditure many times over.

Soil Fertility

The main agricultural question of the humid sections is that of maintaining soil fertility, or of restoring lands depleted of fertility to their former crop-producing power.

The broad areas of virgin soil in the United States, which yield abundantly with little cultivation, have encouraged unwise and wasteful methods of farming. These methods have resulted in land almost or quite depleted of its fertility, until there are many sections where the soil no longer responds to cultivation with profitable crops. The problem of restoring these lands to productive power and of preventing other land from becoming barren is one that scientists and farmers together have partially solved.

How Land loses Fertility. — (a) As different plants take different elements or different amounts of the same elements from the soil for food (see page 101), a given crop planted in the same soil for years will

deplete the land of those elements. (*b*) The soil, through lack of proper cultivation or drainage, loses its capacity for holding moisture and so is unable to bear crops, although rich in plant food elements, as these elements enter the plant only in solution. (*c*) Wind and water bear away much of the fertility of the soil. (*d*) The condition of the soil may be such that the microscopic organisms (see page 76) cannot thrive, and therefore the plant does not thrive. (*e*) The supply of humus may be exhausted, which will result in a decreased supply of nitrogen and mineral plant food associated with the humus (see page 32), will render the soil less able to hold moisture, and will lessen the formation of organic acids which help to make plant food available.

Sooner or later one or more of these causes will operate to render the richest land barren if the farmer does nothing to counteract them.

Elements of the Plants. — Chemical analysis of the tissues of many plants has revealed the presence of some fourteen elements in varying combinations. Only two of these are derived directly from the air, carbon and oxygen, in the form of CO_2, and hydrogen, and these three form about nineteen twentieths of the tissues of plants, the remaining one twentieth being composed of elements supplied by the soil. Of these soil elements, only four need our special attention, nitrogen, phosphorus, potassium, and calcium, for these are the only elements which must be supplied by man, nature's supply often being insufficient.

Note. — Recent investigation by Professor Hart of the Wisconsin Experimental Station seems to indicate that sulphur may also be deficient

in many soils, and that this element should be included in the list of limiting factors in crop production.

Fertilizers. — A fertile soil contains in the requisite amount all the elements not directly derived from the air that are necessary for the nutrition of plants in a form easily available by them. Crop-growing, among other causes, tends to reduce this fertility. The breaking up and decay of rock and the deposits from the air brought down by rain and snow will restore something of this fertility, so that crops may still be grown upon the soil; but if the farmer wishes the maximum yield from his land, he must supplement nature's work by himself, supplying in one form or another, directly or indirectly, the exhausted elements to the soil, that is, by adding fertilizers.

Classes of Fertilizers according to Elements. — When a soil has sufficient moisture, there is generally little or no need of supplying any of the elements of plant tissue except nitrogen, phosphorus, potassium, and occasionally calcium, for the others will be present in the soil in soluble form in sufficient quantities for the plant. But the four named are often lacking or, being present in the soil, are not in available form, in which case they must be supplied or made available if profitable crops are to be grown. The fertilizers that supply the first three are called nitrogenous, phosphoric, potassic, according as nitrogen, phosphorus, or potassium predominates in the compound. Calcium is found in every part of the plant, more lime being found in the leaves than in the other parts. Its artificial application will be discussed later.

Conservation of Soil Fertility. — It is possible by

careful tillage, by rotation of crops, and by utilizing the straw and manure of the farm to postpone the exhaustion of the plant food elements of the soil. If, however, crops are sold year by year from the farm, either in the form of grain, hay, or live stock, the soil from which these crops come must become less productive.

What plant food is removed from the soil in crops must be returned to the soil in some form, if the fertility is to be maintained. It is the province of the farmer to secure from the soil as large a crop as possible, sell it for as high a price as he can get, and put back into the soil the fertility removed from it at as small an expenditure as possible.

Fertility removed by Different Crops. — As will be seen from the table in the Appendix, different crops
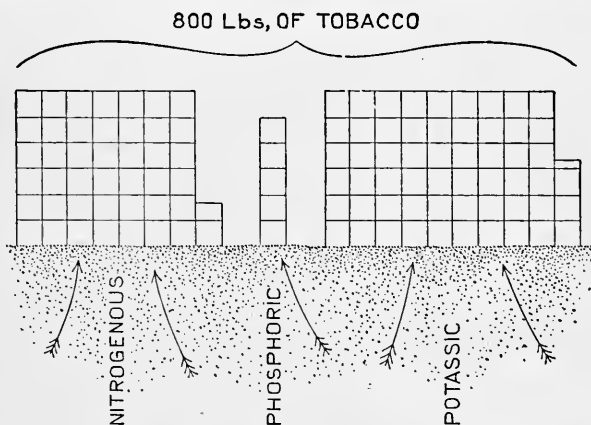

FIG. 37. — Showing the Pounds of Plant Food removed by 800 Pounds of Tobacco.

remove different proportions of the important plant foods containing nitrogen, phosphorus, and potassium.

If 800 pounds of Virginia leaf tobacco are raised and removed from an acre of land, the main elements removed are as indicated in Figure 37 :

Nitrogenous 43.7
Phosphoric   5.0
Potassic   57.3

Average barnyard manure contains to each 1000 pounds 5 pounds of nitrogenous, 3 pounds of phosphoric, and 6 pounds of potassic plant food as shown in Figure 38.

It is evident that if the fertility of the soil removed by the 800 pounds of tobacco is to be restored by the application of manure, there must be applied more than 8000 pounds an acre to replenish the nitrogenous food or more than 9000 pounds to restore the potassic element. In either case there would be more of the phosphoric supplied in the manure than would be required by the tobacco. This would, of course, do no harm, but fertilizers containing a larger proportion of nitrogen and of potassium might be obtained at a lower cost than the large quantity of manure required.
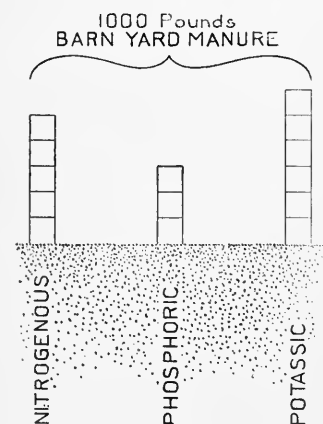

FIG. 38. — Showing the Number of Pounds of Plant Food in 1000 Pounds of Barnyard Manure.

In many cases the easiest and best way to obtain a supply of nitrogen for crops is by growing leguminous plants, such as clover, alfalfa, peas. and beans. These

plants, through the action of the bacteria on their roots, take the nitrogen of the air and make of it a nitrate for the use of the plant. (See page 113.)

To gain the nitrogen and not to remove from the soil the other necessary food substances, these crops should be turned under and not harvested. Figure 39
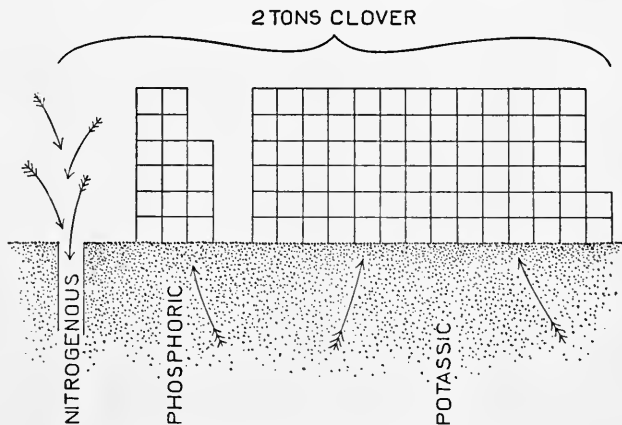

FIG. 39. — Showing Plant Food taken from Soil by Clover.

shows that in a clover crop of two tons taken from an acre of land there is an increase of nitrogen, but there is a great decrease of phosphorus and of potassium.

Note. — Under normal conditions of soil fertility, the clover plant will obtain a part of its nitrogen from the soil and a part from the air. It has been estimated that the part of the clover plant removed in a crop as hay will contain just about the amount of nitrogen obtained from the air, the nitrogen in the roots and stubble representing the amount obtained from the soil.   If this estimate is correct, it is evident that the soil will neither gain nor lose this element when the hay is removed.

When legumes are grown and the crops removed from the land, some means should be taken to replace the phosphorus and potassium taken from the soil.

The average yield of wheat on an acre in the United States is about 15 bushels, or 900 pounds, while the yield of oats is 30 bushels, or 960 pounds, an acre.
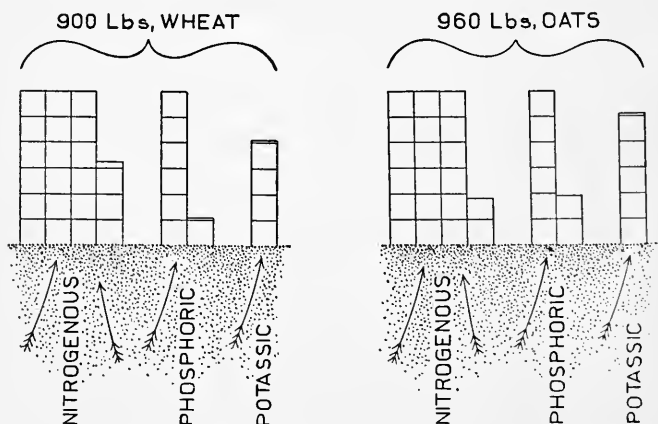

FIG. 40. — Showing the Plant Food taken from Soil by Wheat and by Oats.

It will be noticed that there is very little difference in the decrease caused by these two grains. The fact that virgin soil that is well supplied with plant food will produce from 30 to 50 bushels of wheat an acre and that the average yields in this country are less than half the maximum yields shows the results of constant cropping without proper fertilization. Some of the European countries are now producing from 30 to 50 bushels of wheat an acre by adding fertilizers.

About 30 bushels of corn are raised on an acre in this country. This crop, it will be observed, removes more fertility than either wheat or oats. The frequent

cultivation also has a tendency to decrease considerably the humus in the soil. To get maximum crops of corn and to maintain the fertility of the soil, liberal applications of animal manure and of mineral fertilizers should be made.

Classes of Fertilizers according to Source. — A farm that is well organized and well managed has usually in its own products nearly all of the fertilizers needed to keep itself in a productive condition. By the occasional plowing under of certain green crops, called *green manuring*, much humus is returned to the soil, while the careful conservation and proper use of *animal manure* from the barnyard renders unnecessary so much of other fertilizers.

Farmers who do not have animals on the farm and thus provide for a plentiful

FIG. 41. — Showing Plant Food taken from Soil by Corn.

supply of barnyard manure, and who do not green manure their land, must resort to what are known as commercial fertilizers; that is, compounds of nitrogen, phosphorus, and potassium prepared or manufactured. These fertilizers are expensive, especially those containing nitrogen, but some farmers use them and let the manure go to waste.

Green Manure. — Crops of buckwheat, rye, clover, or cowpeas are sometimes planted to be plowed under with the purpose of adding humus to the soil through
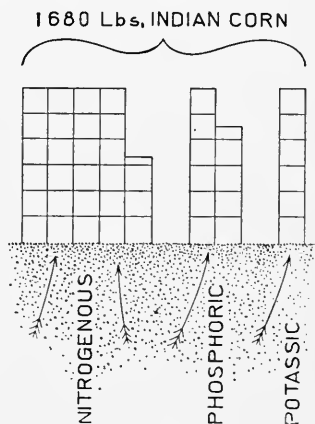
the decay of the plants; the plowing under is done in the spring before the plants have attained sufficient growth to exhaust the moisture of the soil. It is not to be supposed that a farmer would sacrifice in this way a crop that is worth harvesting, except in extreme cases. If stock is kept on the farm, a good crop may be utilized for fodder and the manure will serve to furnish humus and elements of fertility. Farmers who do not keep stock will find themselves forced to use green manure or apply commercial fertilizers to keep their land from getting sterile.

Animal Manure. — Animal manure contains not alone the indigestible portions of the food eaten by the stock, but also worn-out animal tissues. It contains nitrogen, phosphorus, and potassium. Average barn-yard manure has 10 pounds of nitrogen, 6 pounds of phosphorus, and 12 pounds of potassium to a ton, these three plant elements being the ones most likely to be needed in soil that has been cropped often. The quality of animal manure depends upon the food eaten by the animals, and their age and condition. If fed on cotton-seed meal, for instance, their manure will contain from 75 per cent to 90 per cent of the fertilizing value of the meal originally fed, but considering all the foods eaten by live stock about one half of the fertilizing elements eaten are returned in the manure.

Amount of Manure produced by Animals. — From the study of a table computed from the amount of manure produced annually by the different farm animals and the relative richness of the same in nitrogen, phosphorus, and potassium, we learn that on the basis of 1000 pounds of live weight, the horse produces about 12 tons of manure (including bedding), which

contains a sufficient amount of the three elements to be worth about $40 at the average price of the same amount of these elements in commercial fertilizers: the cow, 14 tons, worth $39; the sheep, 9 tons, worth $45; the calf, 14 tons, worth $40; the pig, 18 tons, worth $80; fowls, 4 tons, worth $68. Sheep manure is more valuable because it is drier.

Young animals furnish manure less rich in nutriment than more mature ones. Fowls yield the richest manure on the farm, but as said before, the quality of all manure depends largely upon the quality of the food.

Note. — It has been computed that about 2 tons an acre each year is enough manure for ordinary crops. One cow or horse or its equivalent for each $5\frac{1}{2}$ acres of land will furnish the required amount of manure.[1]

Uses. — Animal manure is rich in plant food, especially the nitrogenous compounds, hence it enriches the soil by the addition of nitrogen as well as phosphorus and potassium. But it does even more. It favors the development of nitrate-forming bacteria in the soil, and also changes the potash, lime, and phosphorus of the soil into more soluble forms.

Note. — By the decay of organic matter organic acids are formed. These acids — carbonic, humic, and nitric — act upon insoluble compounds of potassium and phosphorus and make them soluble. Thus animal manure and green manure by their decay render plant food available.

As liquid manure contains the plant food in available form for the plant to use, it is especially valuable as a fertilizer. Manure, through its adding humus to the soil, also renders the soil more capable of holding moisture.

[1] Roberts, *Fertility of the Land.*

Care of Manure. — The great sources of loss in the value of manure are: (1) leaching, that is, percolation of water through it, (2) running off of the liquid portion, and (3) fermentation, by which nitrogen escapes as ammonia or in other gaseous nitrogen compounds. If loss is to be prevented, the causes of loss must be removed. If manure could be put on the land as soon as made, all its fertility could be utilized and the labor expense of handling it twice would be saved; but as this is not always practicable, the next best thing is to save as much of its richness as possible. Manure left where it will get the drippings from the eaves, or open to rain and snow, will lose half its value through leaching. This may be prevented by covering the manure. Many farmers now build covered barnyards, so that the manure is not leached by the falling rain and snow nor dried so quickly by the sun and wind. The stock pack the manure, and this helps to keep it moist and prevents fermentation. If straw is used for bedding, it will help to absorb the moisture, while it in itself will, by its decay, furnish plant food.

If a cement floor is used, still further loss is prevented. The addition of acid phosphate or gypsum to the manure pile will retard the fermentation and thus help to retain the nitrogen. (See pages 55, 117.)

Note. — Shavings or sawdust are often used as bedding, and when straw cannot be obtained they are necessary substitutes. Shavings contain very little of the fertilizing elements, and their decay, when mixed with the manure, is very slow. On this account straw is preferred for bedding.

Application of Manure. — Many farmers apply manure in the late summer or fall and harrow it in. If

left on the surface of the ground, the soil does not receive all its fertilizing value, as part may wash away. As fresh manure injures some crops, there is danger in applying it in the spring unless thoroughly cured, or rotted. Plants, if supplied with plant food in too great abundance, are likely to overeat somewhat as animals do, so it is better to apply the manure frequently in small quantities on the land with comparatively long periods between applications.

The best results are obtained when rock phosphate or acid phosphate and some fertilizer containing potassium are applied with the manure. Wood ashes or sulphate of potassium will furnish potassium.[1]

Economy of Manure. — The cash value of animal manure is usually estimated by ascertaining what the same fertilizing value in commercial fertilizers would cost. The price of nitrogen may be placed at 17 cents a pound; the other two elements are each worth about 6 cents a pound. A fertilizer containing 10 pounds of nitrogen, 6 pounds of phosphorus, and 12 pounds of potash, which is the proportion of these elements in a ton of manure, would cost $2.78, which means that the

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[1] Professor Chilcott has this to say of the application of manure:

"The farmer should fully understand that while the application of barnyard manure to the soil is certain to have a beneficial effect by adding to the store of plant food, its effect may not be apparent in the results of the first crop after application; and that the immediate physical effects upon the soil may be either beneficial or detrimental, depending upon the character of the soil, the kind of manure, the time and method of application, the nature of the crop and the character of the season as to moisture and temperature.

"The soil of the farm should be considered a bank in which the surplus resources of the farm, in the form of plant food, should be deposited with the understanding that the surplus cannot be withdrawn at once, but it is to remain until such time as the conditions are favorable for its utilization."

farmer has in each ton of the waste product from his stock $2.78 in fertilizing value to restore his land, with no expense except the labor of caring for it and applying it. This last expense would have to be borne in hauling it away if not used, so this need not enter into the calculation. Taking into consideration these figures, it seems scarcely credible that farmers will give away or sell their manure to more thrifty neighbors or so neglect to protect it that it loses a large percentage of its nutritive soil value. Yet many farmers still continue this wasteful, improvident practice, and then purchase commercial fertilizers when their land has become infertile.

Commercial Fertilizers. — The materials for making these fertilizers are the by-products of the slaughter and meat-packing houses, like bone meal, dried blood, or tankage (waste material); natural products of the earth that are mined, like Chile saltpeter (sodium nitrate), phosphate rock, kainit (a mineral composed of magnesium sulphate, potassium sulphate, and magnesium chloride found in Germany); by-products of gas and coke manufacture (ammonia sulphate); or vegetable products, like wood ashes and tobacco stems.

The value of the commercial fertilizers has nothing to do with their origin, but depends entirely upon the quantity and the form in which the plant food exists in them, whether in soluble form and directly available to the plant or in a form which must first be acted upon by other agencies before being used by the plant. (See page 107.)

Amounts to Use. — Commercial fertilizers are used for the same purpose as manures to restore or maintain the fertility of the soil. Most authorities are agreed that each acre of land, in order to show the maximum

productive results, will require at least 10 pounds of nitrogen, 15 pounds of phosphorus, and 20 pounds of potash each year, but the amount of any fertilizer required can never be stated in exact figures, for different soils and different plants need varying amounts, so that any figures are misleading, experience being the only safe guide in determining the quantity to be used. It is also necessary to know what *available* amount of the needed elements any given fertilizer contains, in order to estimate how much of it to use.

The following table is useful for reference as it gives the approximate percentage of food elements in the most common commercial fertilizers :

	NITROGEN	SOLUBLE PHOSPHORUS	INSOLUBLE PHOSPHORUS	POTASH
Nitrogenous	%	%	%	%
Chile saltpeter . . .	$15\frac{1}{2}$–16			
Ammonium sulphate .	19–$20\frac{1}{2}$			
Dried blood	12–14			
Castor pomace [1] . . .	5–6			
Phosphoric				
Bone black		17	1–2	17–18
Ground bone . . .	$2\frac{1}{2}$–$4\frac{1}{2}$	5–8	15–17	30–35
Thomas slag . . .		9–18		
Potassic				
Muriate of potash . .				50
Sulphate of potash . .				48–52
Kainit				13–$13\frac{1}{2}$
Wood ashes		1–2		3–5
Tobacco stems . . .		3–5		5–8

[1] Refuse from extracting oils from castor bean.

It will be readily seen that in order to obtain all three elements it will be necessary to make a fertilizing mixture. For instance, to obtain the 10 pounds of nitrogen needed for one acre, about 65 pounds of Chile saltpeter will be required; for 15 pounds of soluble phosphoric acid, it will take 100 pounds of bone black, and 160 pounds of kainit or 40 pounds of muriate of potash to furnish the potash needed.

Note. — In mixing fertilizers care should be taken that combinations are not made that will release any food element that will be lost in the air or that will lock up in chemical combinations food elements so that they are not available. Figure 42 will aid in avoiding error.

Superphosphate

Lime

Thomas Phosphate

Sulphate of Ammonia

Farmyard Manure and Guano

Potash Salts

Kainit

Nitrate of Soda
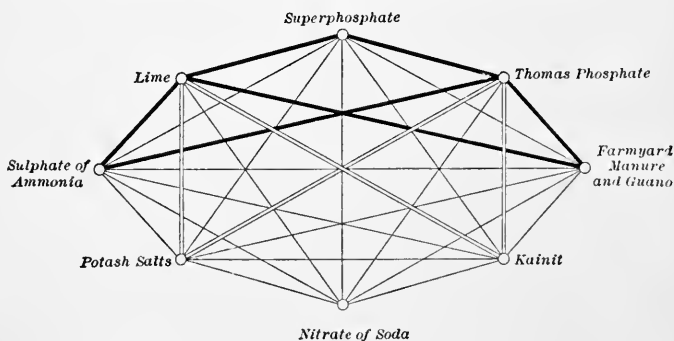
Fig. 42.

Substances connected by thick line must not be mixed together. Substances connected by double line must be mixed only immediately before use. Substances connected by single thin line may be mixed together at any time. After Geekens.

Application. — The manner of applying commercial fertilizers depends upon their form, whether soluble or insoluble. If the former, they may simply be scattered over the surface of the land, for the rains will cause them to mix with the soil. If insoluble, they should be mixed with sand or ashes, spread as evenly

as possible over the surface, then plowed or harrowed in, for if they are not thoroughly mixed with soil, they will do little good.

If immediate results are desired in the form of a large yield, soluble fertilizers must be applied in the spring, but if the soil is to be gradually enriched by their use for a number of years, a slow, insoluble fertilizer should be put on in the fall.

Nitrogen. — Much has already been said about the need of nitrogen. The atmosphere is largely composed of this element, about 80 per cent, and yet plants surrounded with air may starve for lack of nitrogen. The reason is that they are so constituted as to be unable to take in the free nitrogen of the air. The air must first enter the soil, and there give up its nitrogen to make soluble nitrates — nitrogen compounds — before the plant can take it in and use it. A small amount of nitrates — nitric acid and ammonia — falls with rain and snow and enters the soil, but as this is variable and insufficient for plant needs, we must consider what the conditions are under which soluble nitrates are formed in the soil, in order to understand how plants get their needed food.

Legumes. — It has remained for modern science to explain a fact well known in ancient times, that other crops yield more abundantly when the land has been sown to clover, peas, or beans the preceding year. We now know why this is so. These plants and their kind, known as legumes, or pod plants, have little swellings, or tubercles, on their roots, caused by certain small organisms, called bacteria. Through the agency of these microscopic plants the free nitrogen of the air and that found in organic matter in the

soil are combined with other elements in the soil to form nitric acid (HNO_3). This acid combines with certain substances, such as lime, soda, iron, and the like, to form soluble nitrates. They are readily available to the plant.
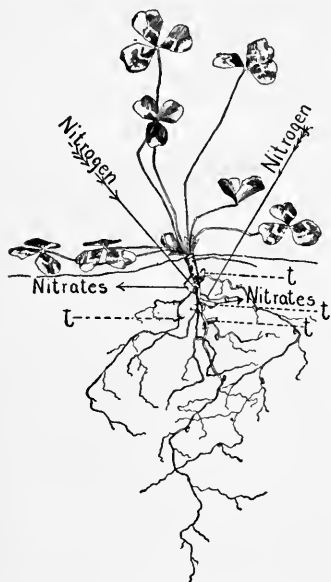
This process is called *nitrification*. The roots of legumes furnish homes for the nitrogen-fixing bacteria, which abound in nearly every soil. When a crop of these plants is plowed under and decays, great richness is added to the soil. Nitrification, or fixation of free nitrogen, as some call it, goes on most rapidly when the soil is moist and well warmed, because heat and moisture favor the growth of bacteria. This explains, in part, why properly drained, thoroughly tilled land produces better crops.

FIG. 43. — Tubercles on Clover Roots.

It is thus seen how soil poor in nitrogen may, by the action of bacteria on legumes, be fertilized from the inexhaustible supply of nitrogen in the air. The Department of Agriculture has made a thorough study of this subject, and has succeeded in working out the complete life history and habits of the bacteria in the root tubercles.

They have also discovered a cheap and thoroughly effective way of distributing and applying these or-

ganisms. At the cost of a few cents a bushel the seeds of peas, beans, clover, alfalfa, or any other legumes may be inoculated with these bacteria, thus making it possible to secure good crops on soils poorly supplied with nitrogen, and at the same time leave a large amount of the element fixed in the soil available to wheat, corn, potatoes, or any other crop that may follow the legumes. The bacteria are helped to live and multiply by their host plant, the host in turn is supplied with nitrogenous food by these bacteria, and the host, upon dying, leaves its decaying roots, leaves, and stems to supply stored-up nitrogen to succeeding crops or to neighboring plants which may outlive the legume and feed upon its disorganized parts.[1]

Experiments are being conducted at different experiment stations to ascertain whether nitrogen fixation can be secured without legumes, but while there has been a degree of success attained, the work is yet in the experimental stage.

Note. — If legumes are grown in soil well supplied with compounds of nitrogen, as nitrates, tubercles will not grow on the roots. Bacteria will fix nitrogen from the air when the plant needs it for its growth. When the soil is poorly supplied with compounds of nitrogen, tubercles on the roots of the legumes grow in large numbers and often in large clusters.

Denitrification. — While the work of certain bacteria through nitrification is beneficent to the plant world, there are others of these microscopic plants that accomplish the opposite result, in that they act upon the nitrates, breaking up these compounds and restor-

[1] See Farmers' Bulletin, 315; Progress in Legume Inoculation.

ing free nitrogen to the air, a process called *denitrification*. Through this process animal manure, left exposed to the weather and not packed down, loses much of its nitrogen and therefore its fertilizing value. Soil often loses soluble nitrates through the operation of this cause and thus becomes less able to produce good crops. Cover crops, that is, crops left unharvested so that they may protect the surface of the ground, will retard denitrification.

Acidity of Soil. — Farmers have long been familiar with what they call a *sour* soil. A poorly drained soil will easily become acid, but it is equally true that a well-drained one may also reveal the same condition. Sometimes this acidity is due to lack of ventilation in the soil, sometimes to the presence of too many trees shading the ground, sometimes to the excessive use of fertilizers, and sometimes to the leaching of the soil. It is also true that some plants through the action of their root tips render the soil acid, and that decay of organic matter will produce the same result.

Note. — Investigations by Professor Whitson of the Wisconsin Experiment Station have shown that long-continued cropping on upland clay soils renders them acid, and that these acid soils respond readily to an application of rock phosphate.

Suggestive Experiment. — Collect from a few inches below the surface small quantities of soil from different places where there might be reason to think that acid soils might be found. After thoroughly moistening the soil, place a small piece of blue litmus paper in each sample, cover the paper completely with the soil and leave it for five minutes. If, on examination, the paper has become distinctly red, you may know that the soil is sour, for an acid always has this effect on litmus. (See page 23.)

Legumes and some other plants grown in acid soil will not thrive well; but if a little slacked quicklime is added to the soil, or preferably, larger quantities of ground limestone, beneficial results soon follow, for lime neutralizes the acid. Lime does more for vegetation than this. It helps greatly in rendering other plant foods available by hastening the decay of organic matter and rendering insoluble phosphoric and potassic compounds soluble.

Gypsum, a form of lime, fixes ammonia, hence it is often sprinkled on manure piles to prevent the escape of this substance.

CHAPTER III

AGRICULTURAL BOTANY

Parts of the Plant. — In general, the plant has four essential parts; namely, the *root*, which generally grows in the soil, the *stem*, which in most instances grows
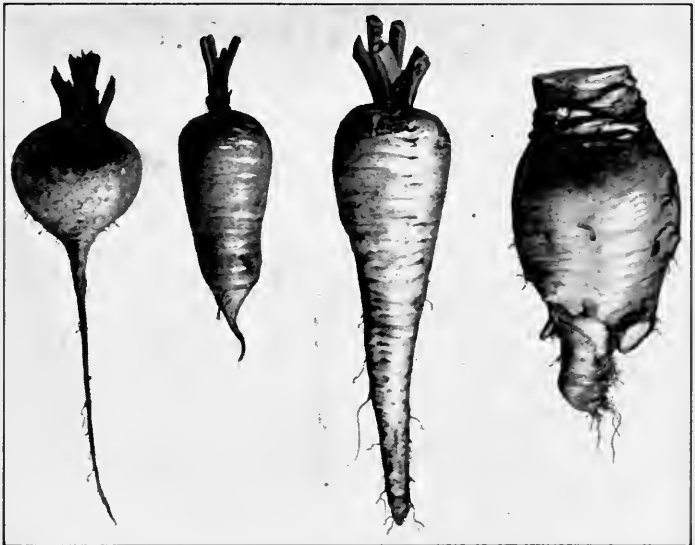
Beet   Carrot   Parsnip   Mangel-wurzei

Fig. 44. — Roots used for Food.

above the ground, the *leaves*, which grow on the stem or branches of it, and the *flower* or *fruit producer*,

which also grows on the stem or its branches. The life of the plant culminates in the seed, which it is the whole office of the plant to produce, for the seed, containing as it does the germ of another plant, is an important means of perpetuating the species.
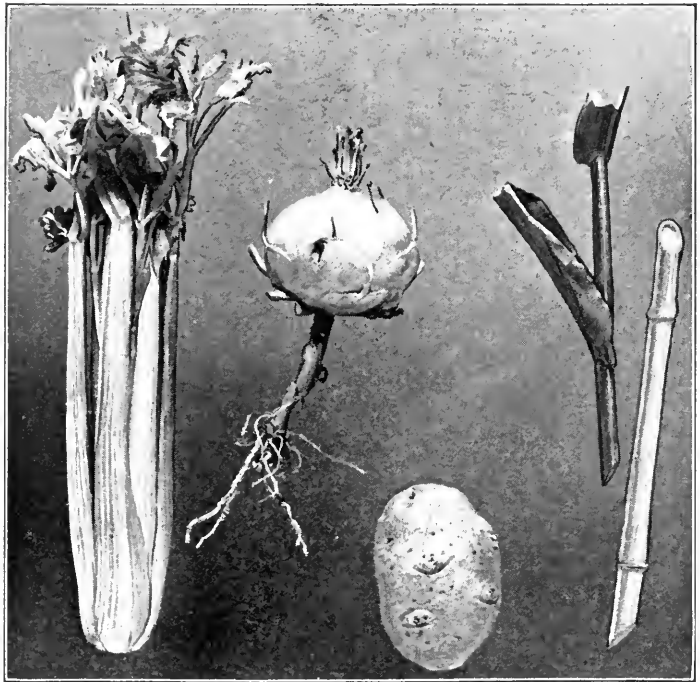
Celery   Kohl-rabi   Potato   Sugar cane

FIG. 45. — Stems used for Food.

Food Products from Plants. — Food products are obtained from all parts of the plant. The *root* may be enlarged by storage of food, as in the beet, carrot, sweet potato, and turnip.

The *stem* may serve as food for stock either in its green state as hay, or dried state as straw.   For human

Cabbage   Onions   Lettuce

FIG. 46. — Leaves used for Food.

food we have the potato (an underground stem), sugar cane, celery, and asparagus, as illustrations.

Leaves become thickened and furnish food, as seen

Wheat   Nuts   Pear   Melon

FIG. 47. — Products of the Flower used for Food.

in the cabbage and the onion.   With the stem they make hay for live stock, as in clover and alfalfa.

Our most important food supply comes from the *flower*, or rather the seed which the flower produces. Grains, fruits, nuts, and melons are well-known examples.

The Root. — The root of the plant in most instances extends below the surface of the ground, fixing the position of the plant and taking from the soil water containing the dissolved mineral food that the plant needs. As a rule, the root springs from the stem, and not the stem from the root.

Primary Roots. — The seed, when put under the right conditions of moisture, air, and temperature, begins to sprout, or germinate. It sends downward a *primary* root. This may later branch and subdivide until it is entirely lost in its divisions, or it may continue in one main root, having small side branches only, as in the carrot and radish. The branches from the primary roots are called *secondary* roots.

Fig. 48. — Plantlet of Indian Corn, showing Primary Root.

Adventitious Roots. — Under favorable conditions any part of the stem may produce roots. These usually come from parts where leaves or branches would naturally spring, but sometimes they grow from other parts of the stem. In either case they are called *adventitious* roots. Because of this tendency in stems to send off roots from different parts, some plants may be multiplied by cuttings; that is, by cutting a slip of the stem and planting it in moist soil, in sand, or in water.

Classes of Roots. — When a root of a plant divides and subdivides into numerous small, threadlike forms,

or rootlets, it is called a *fibrous* root. Nearly all grains and grasses have fibrous roots.

FIG. 49. — Roots of an Oat Plant, showing Fibrous Root.

Some roots are storehouses of food for the nourishment of the plant itself and the production of seed the following year. They consist of a large main root with small side branches. Such roots are called *fleshy* roots, or *taproots*. The carrot and turnip are good examples. (See Figure 44.)

Note. — *Parasitic roots.* Another class of roots, based on mode of feeding rather than on form, is called parasitic roots. These roots are found on such plants as mistletoe and the common dodders, which grow on flax, clover, alfalfa, and other plants. These are peculiar roots which penetrate the tissues of the plants upon which they live, taking their nourishment from these plants.

Root Hairs. — Figure 50 shows some very young radish plants. Notice that each root is clothed with a downy fringe that looks like the finest silk. These delicate, hairlike structures are called *root hairs*. The purpose they serve is to absorb the soil water with the food materials it contains. The root hairs greatly increase the absorbing surface of the plant below ground. Each root hair consists of a single elongated cell,

FIG. 50. — Young Radish Plants.

filled with a mucilage-like substance called protoplasm, and a thinner, more watery substance called cell sap. As the end of the root pushes through the soil by growth, new root hairs are formed in front of the older ones, while those farthest back as rapidly die off, so that at any given time only a short portion of a rootlet bears hairs. A root hair never develops into a rootlet.

It is usually difficult to see the root hairs of plants growing in the ground, but with the help of a magnifying glass they may be discovered if the particles of soil about the younger roots are carefully removed.

Suggestive Experiment. — Place flax, clover, or timothy seed on moist blotting paper. Keep the blotting paper between two plates to prevent evaporation. Notice the velvety covering to the roots. These are the root hairs above described.

Uses of Root Hairs. — Root hairs can take up water freely, even from soil that does not appear very wet, because each particle of soil, against which the hairs lie very close, is surrounded by a thin layer, or film, of water. Another thing of interest concerning root hairs is that they are able, by means of an acid which exudes from their tips, to aid in dissolving the mineral matters in the soil which the plant needs for food.

As the root hairs, then, aid in the work of solution and do nearly all the work of absorption of the food the plant obtains from the soil, it follows that the amount of nourishment a given plant can receive from the ground depends upon the number of the root tips, the only part of the root which bears root hairs.

Suggestive Experiment. — On a small piece of polished marble place some fine seed and keep the surface of the marble moist under a cloth or blotting paper so that the seeds may germinate. As

the roots spread over the surface, slight grooves will be etched through the polished surface of the marble. This is done by the acid that the root hairs give out.
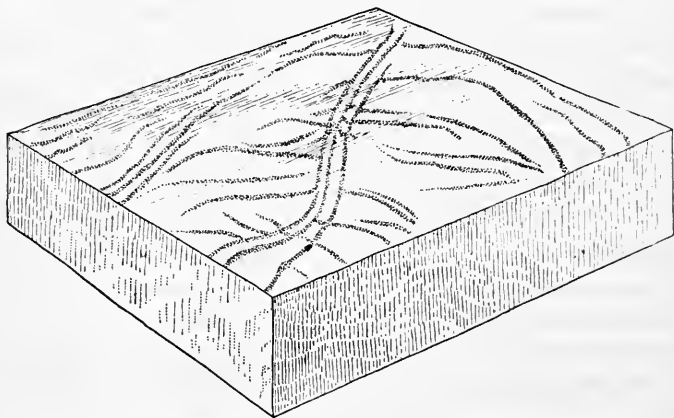

FIG. 51. — Marble corroded by Bean Roots (Minnesota Experiment Station).

Osmosis. — To understand just how the root hairs absorb moisture and plant food held in solution, it will be necessary to examine more closely the structure of the hairs. As stated above, each root hair is a cell filled with protoplasm and cell sap. The former usually lines the inner surface of the cell wall and has one portion more dense, called the *nucleus*. The nucleus is supposed to be the center of the life of the cell, but its use is really little understood.

The cell wall has no pores, or openings, that can be seen with the highest power microscope made, yet water can pass through the wall with ease. It has been found that some plants having a large root surface have absorbed many times their own weight of water in twenty-four hours through the thin walls

of the root hairs. This process of absorption is called *osmosis*.

Suggestive Experiment. — Dissolve in water all the sugar that the water will hold ; that is, make a saturated solution of sugar and water. Invert a small glass funnel or a thistle tube over the larger end of which a bladder or other animal membrane has been tightly tied, and pour in some of the sugar solution. Lower the funnel or tube into a glass of water until the water in the glass and the solution in the funnel are at the same height. Let this stand for a few hours. It will then be observed that the solution has increased in volume, that is, has risen in the tube. The water in the glass must have passed through the membrane and diluted the sugar solution. This passage has taken place notwithstanding the fact that there are no pores in the membrane which the highest power microscope can reveal. This passage of a liquid through an animal or vegetable membrane is called osmosis.
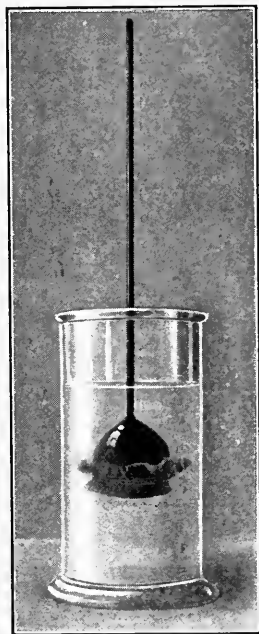
FIG. 52. — Experiment illustrating Osmosis.

General Laws of Osmosis. — *First Law.* Two liquids separated by a membrane will mix, and the more rapid flow will be toward the liquid having the more dense solution. That is, if water containing solids in solution is separated from pure water by a membrane, the greater flow will be through the membrane from the pure water into the solution.

Second Law. Substances that crystallize readily and are easily dissolved, such as salt and sugar, pass

through membranes easily, while mucilaginous, or jelly-like, substances pass through membranes slowly or do not pass through at all.

The passage of water into root hairs, and the retention of the protoplasm inside of the root hair, well illustrate both of these laws. The root hair is surrounded by soil water that is not so dense as the cell sap, which is somewhat sugary. Hence the soil water passes through the wall of the hair into the cell, here mixing with cell sap, thus making it less dense than before. This root hair, or cell, touches another cell. The cell sap in the second cell, being as yet undiluted, is more dense than that in the first, therefore some of the cell sap of this first will pass through the wall of the second and dilute the second. Thus the diluted cell sap is passed on from cell to cell till it reaches the small tubes, or ducts, in the root that carry it into the stem. By the operation of the second law, the protoplasm, or life element of the cell, remains in the cell.

Root Pressure. — This absorptive power of the root hairs causes what is called *root pressure*. This is the force which sends the upward current of water through the plant. Hales, the English physicist, found the root pressure of a grape vine to be equal to the weight of a column of mercury thirty-two and one half inches high. It is probably this force which causes the sap to flow freely from broken stems and from tapped maple trees in spring. Within certain limits it is affected by the temperature of the soil, lessening as the temperature falls. During cool nights, when evaporation from the leaves of plants is not great, the root pressure may be great enough to force water from the tips of the leaves. The drops of water that

sparkle on the foliage of plants in the sunlight of summer mornings, often mistaken for dew, are usually caused by root pressure.

Systems of Rootage. — The roots of some plants, grasses, and grains, for example, grow in a fibrous mat
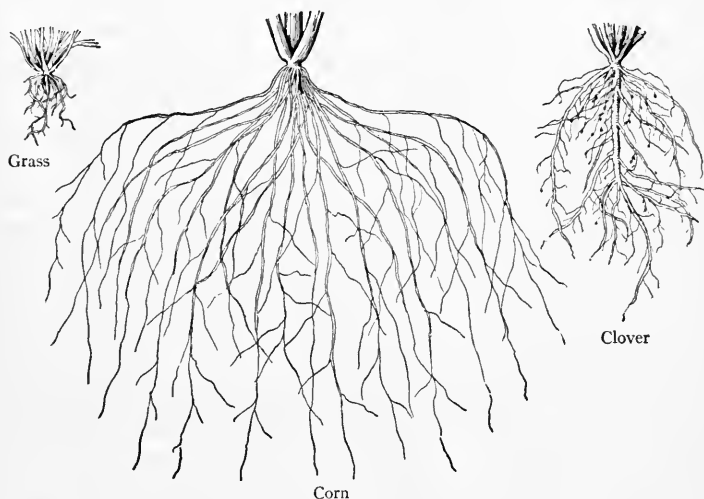

Grass

Clover

Corn

FIG. 53. — Systems of Rootage.

near the surface of the ground. Corn sends its roots out laterally from the plant, and then they turn downward to a considerable depth. Clover has a taproot growing downward, with many branches springing off in all directions.

Plants that send their roots deep into the soil are known as *deep feeders*, while those whose roots lie near the surface are called *shallow feeders*. In general, the extreme depth reached by roots is less than their greatest horizontal extent. The depth to which the root grows probably depends largely upon the

nature of the subsoil and the depth of free ground water, but in most annual farm and garden crops the roots may be found in the part of the soil turned by the plow; that is, from six to ten inches in depth. Plants grown in poor soil will have relatively a much more extended root system than those grown in fertile soil. In a dry season a plant will extend its roots much farther in its search for moisture than in a wet season.

Effect of Trees on Crops. — Trees, as we can readily see, must have a wide extension of root surface in order to hold their position and absorb sufficient soil water. As a consequence, their nearness to a crop cannot fail to affect the growth of that crop except in a very wet season, for they absorb from the soil an enormous amount of water and this deprives the plants of what they must have in order to grow; furthermore, their foliage keeps the much-needed sunlight from the maturing grain.

How Roots Lengthen. — Since roots are buried in the soil and the soil is too heavy and dense to be moved by them in large quantities, they cannot grow throughout their entire length. As a consequence, their real life, or growing power, is limited to a short portion just behind the root tip. The root tip is protected in its pushing movement through the soil by a thimble-like covering, called the root cap. This may be seen by the naked eye if the end of a rootlet of a bean grown in water is examined carefully.

Just back of the center of the root cap the cells increase in number by dividing, the separate divisions growing to the size of the parent cell. Each, then, divides into other cells, which in turn grow to normal size, so that the root cap is constantly pushed forward.

Darwin discovered that the root tip in its search for plant food and moisture does not move straight forward, but seeks for the line of least resistance. As it thus takes advantage of openings in the soil, an oscillating, or pendulum-like, movement results.

Branching of Roots. — The roots of the annual crops grown on the farm branch very freely. This is equivalent to saying that they can take up a large amount of moisture and food from the soil, because the greater the number of root branches, the greater the number of root hairs, or absorbing surface of the root. The root branches usually spread out over the part of the soil pulverized by the plow, for here the plants seem to find the greatest amount of nourishment.

The rapid way in which roots will branch under favor-

Fig. 54. — Roots of Young Wheat Plant.

rh, root hairs, surrounded by grains of soil; *rt*, root tips.

able conditions may be shown by burying a piece of manure in the soil near a plant. In a short time the plant will send its rootlets in all directions through it. An old bone, which contains an abundance of plant food, when buried under the surface of the ground is often found covered with a thick net of fibrous roots.

As the thriftiness of a plant depends upon its root branching, it is important to the farmer to know what will induce the process. It has been found that transplanting, which consists in taking the plant from its place and replanting it in another place, stimulates the branching of roots. It is therefore beneficial to the growth of the plant if done under proper conditions. It is sometimes helpful to a plant to transplant it several times in one season.

Root pruning, or cutting off the root a few inches below the surface, often stimulates the growth of lateral branches, and if done to trees with a taproot, like the walnut and hickory, the year before transplanting usually secures a sufficient growth of rootlets to make transplanting successful.

Plant Food through the Roots. — Although it has been stated that the root hairs cling tenaciously to minute particles of soil, it must not be thought that these particles ever enter the root of the plant.

Root hairs take up as food only mineral matter held in solution. Ordinary soil water contains a large amount of this matter. How it passes into the root to nourish the plant has been explained under osmosis. The power of selecting just the mineral food the particular plant needs and rejecting all other seems to reside in the protoplasm of the cell, but how the protoplasm exercises this power is an unsolved mystery. The protoplasm in the root hair of the barley, for instance, will select a large proportion of silicon from the soil water, while the protoplasm in the root hair of the clover will take only a relatively small amount of the same food, and yet both plants may be growing under identical conditions.

The Stem. — The stem of the plant, the part from which all the other parts of the plant spring, is the axis of the plant. Some stems stand erect and support the whole plant, as in trees and shrubs; others lie on the ground or cling to some object for support, as vines; still others grow underground, and thus seem like roots, but that they are really stems may readily be discovered.

Underground Stems. — Among the underground stems of interest to the farmer are the potato, the quack grass, and the wild morning glory.

The potato is the thickened end of an underground stem. Its true stem character is shown by the buds, *eyes*, it bears. An underground stem like the potato is called a tuber.

FIG. 55. — Potato Plant.

U st, underground stems; *R*, roots; the tubers are the thickened ends of the underground stems. (Much reduced. After Frank and Tschirch.)

The sweet potato, on the contrary, is an enlargement of the root.

The underground stems of the quack grass and the wild morning glory make these two plants great weed pests.

Note. — Canada thistle has been considered a plant with an underground stem, but the running root of this plant lacks nodes, scales, or buds and is therefore properly a root.

Although their stems above ground may be cut off and seeding time prevented, the spread of the plant is not hindered, for the underground stems still grow, plowing or chopping off the stems serving merely to make a

bad matter worse by increasing the number of separate plants. Underground stems of this kind are called *rootstalks*.
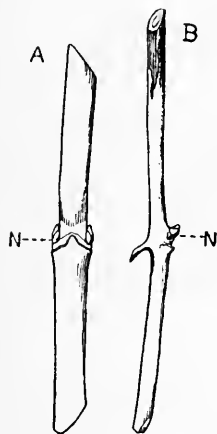
Nodes. — Stems are made up of successive joints, or lengths. At the point where one joint, or section, joins another there is an enlargement of the stem. This, the point where the leaf is often attached, is called a *node*. The section of stem between two nodes is called an *internode*.

If the leaves have fallen, the nodes can be plainly seen by the leaf scars or by the slight enlargement of the stem.

FIG. 56. — Stems of Box Elder (*A*) and Wild Grape (*B*); *N*, Nodes.

Stems and their branches grow by adding sections, or joints, and also by lengthening their internodes.

The internodes of the main stem are longer than those of the branches. The internodes of only the newer parts of woody plants lengthen. If an internode ceases to lengthen during any growing season, it will not usually resume growth, but will remain fixed at that length. When an internode grows rapidly, it usually grows to a considerable length, the length and also the diameter depending upon the rapidity of growth. As might be expected, growth is much more rapid in the spring than in the fall. We may often distinguish the long internodes of spring following the short ones of autumn.

To increase Branching of Stems. — As the stem lengthens the most rapidly just behind the growing point, or tip, of the stem, we may check the growth of the stem by pinching off the terminal node. In this way branching will be increased, because by checking the growth of the terminal node the growing strength of the plant is stimulated at points farther back. This corresponds to the pruning of the root to increase root branching.

Buds. — A bud is a resting growing point. It may develop into a leaf and then is called a *leaf bud*, or into a flower and is called a *flower bud*. The main stem grows by the development of the *terminal*, or end bud, the branches grow by the development of *lateral*, or side, buds. As the lateral buds usually grow in the crotches, or axils, of leaves, they are also called *axillary* buds. Very often there are several buds grouped in some way in a single leaf axil, one above the other, as in the butternut, or side by side, as in the box elder.

FIG. 57. — Buds.
T, terminal; *L*, lateral.

Lateral buds are produced in early summer and usually remain dormant until the next spring, but if the terminal bud is destroyed, the lateral buds may be stimulated to growth the same summer that they are formed. In

FIG. 58. — Sycamore Bud protected by the Petiole.

some plants the lateral buds are concealed beneath the bark during the summer of their formation, remaining invisible until the next summer. Others, for example, the locust and buttonwood, have their lateral buds hidden in a cuplike cavity at the base of the petiole, or stem, of the leaf.

Latent and Adventitious Buds. — Not all of the lateral buds on the stem of a tree develop into branches. This failure of some buds to develop in a normal way may be due to the fact that certain other buds get started to growing well and appropriate all the nourishment. Sometimes these undeveloped buds, called *latent* buds, are destroyed, and sometimes they remain dormant for a number of years. If through pruning, pinching, or injury to newer buds, sufficient nutrition be furnished the latent buds at any time, they may develop and form shoots. This is seen sometimes when trees develop new shoots on the trunk or on the older parts of branches, especially noticeable when early frosts destroy the first buds.

More commonly, however, the irregular shoots coming from the trunk of a tree, as in the elm, or from the roots, which normally do not have buds, as in the silver-leaved poplar, are from *adventitious* buds. These may be defined as buds which occur at irregular or unusual places, that is, not terminal or axillary. They come in no particular order, being caused to grow by some wound or mutilation. The willows, poplars, and chestnuts have young shoots from adventitious buds in large numbers. Some willows are cut back in order to stimulate the growth of adventitious buds, which will form pliable young shoots adapted for basket weaving.

Bulbs and Bulblets. — *Bulbs* are really forms of buds,

having thick, fleshy scales, or leaves, on an exceedingly short stem, the thickened leaves furnishing nourishment
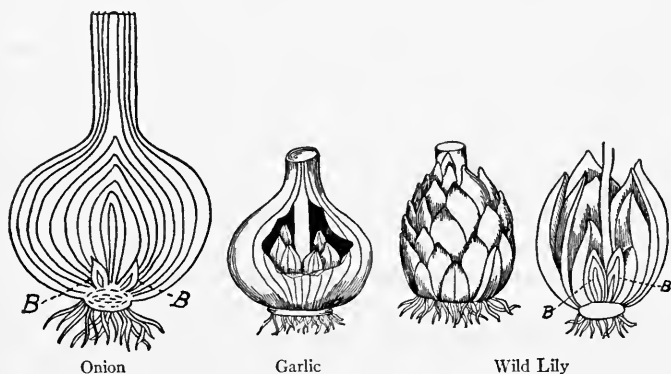

FIG. 59. — Typical Bulbs; *B*, Buds. Notice the Buds (Cloves) of Garlic.

Onion   Garlic   Wild Lily

and protection. In the axils of the leaves are smaller lateral buds. The onion is a good illustration of a bulb.

Bulblets are very small bulbs which appear in the axils of the leaves of some lilies and in the flower clusters of the leek and the onion. They do not develop into branches, but fall from the plant to the ground and there form new plants.

Exogenous and Endogenous Stems. — Flowering plants are divided according to the manner of growth of their stems
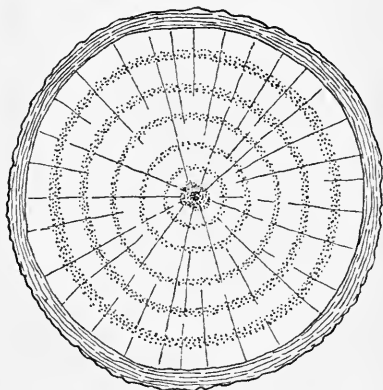
FIG. 60. — Section of an Exogenous Stem.

into two great classes. By far the greater number
of plants are outside growers; that is, the woody part
of the stem is arranged in rings or layers about a cen-
ter, called a *pith*, and outside of this is a corky layer,
called the *bark*. The growth each year occurs by addi-
tion on the *outside* of the previously formed wooden
rings, although inside the bark. The outside growers
are called *Exogens*, or *Exogenous* plants.

Note. — The inner bark of the stem contains some very fine ducts,
or tubes, called sieve tubes. Through these tubes the larger part of
the liquid food prepared in the leaves is passed to parts of the plant for
storage or to increase the size of the plant. The flow of sap in general
is, then, upward through the sapwood, and downward through the sieve
tubes of the inner bark. Besides this there is a considerable movement
of sap from one cell to another, both upward, downward, and laterally.

Between the bark and the sapwood is a very thin
layer, or zone, that is the growing part of the tree. It is

called the *cambium* layer.
It is well supplied with
cells filled with proto-
plasm. In spring this
layer becomes so gorged
with nourishment that
if a twig of hickory or
willow is pounded, the
cambium layer is broken
up and the bark may be
slipped off the wood.
Boys utilize their prac-
tical knowledge of this
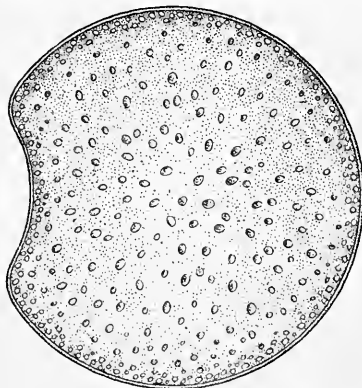in making whistles. It

Fig. 61. — Section of an Endogenous Stem.

is the same fact that tempts goats and calves to bark
trees in the spring, and enables savages, in time of

drought, to live for a long time on the buds and bark of trees.

When the cambium layer of an actively growing stem is held in contact with the same layer in another growing stem of the same kind or of a closely similar kind, the two may grow together at the point of contact. It is this fact that makes grafting possible. (See page 159.) The stems of endogens, or inside growers, have prominent nodes and are hollow, as in the grasses and the bamboo; or the center of the stem is filled with pith, as in the corn stalk. The pith is traversed with fibers which are bundles of tubes with other vessels and fibers.

Leaves. — The leaves of any given species of plant grow from the nodes of the stem in a well-defined arrangement which rarely varies in that species. They

Alternate   Opposite   Whorled
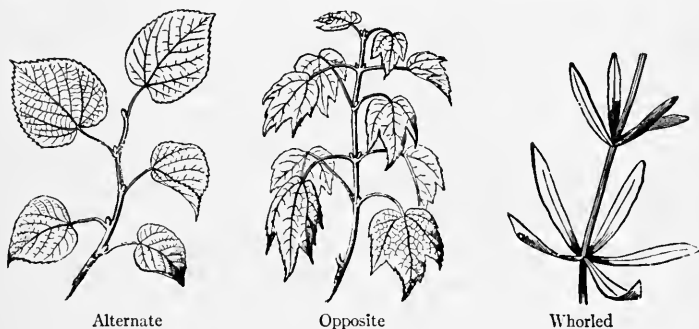
FIG. 62. — Arrangement of Leaves.

may have an *opposite* arrangement, that is, with two leaves, one on each side of the node, or they may have an *alternate* arrangement, that is, one leaf at a node. Occasionally there are more than two leaves at a node with the space around the stem divided equally among them. This is known as the *whorled* arrangement.

Get a number of twigs and examine the leaf arrangement.

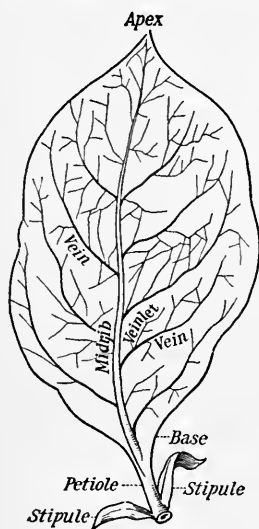**Parts of the Leaf.** — The main part of the leaf is called the *blade*. The blade is attached to the stem or branch by a *petiole*. At the base of the petiole, and sometimes clasping the stem, are often found leaflike or thorny appendages, called *stipules*. The part of the blade farthest removed from the petiole is called the *apex*. The part of the blade nearest the petiole is called the *base* of the leaf. The framework of the blade is made up of fibrous material, called *ribs* and *veins*. From the base of the leaf, running through the blade to the apex, is the largest of the ribs, called the *midrib*. The branches are called *veins*, and the smaller ones *veinlets*.

FIG. 63. — Parts of the Leaf.

Venation of Leaves. — Venation is the plan of distribution of ribs and veins to the leaf blade. Leaves are either *netted-veined* or *parallel-veined*.

Netted-veined leaves, as the name indicates, have veins branching from the midrib, dividing and subdividing until the whole leaf blade is covered with a fine network. This venation is clearly shown in the leaf of the beet, the oak, and the maple. In general the exogenous plants are netted-veined.

Parallel-veined leaves have small parallel ribs running from the base of the midrib throughout the blade, but without branching, although there are minute

veinlets joining the parallel veins. For this venation examine the leaves of grass, corn, and the lily. Nearly all endogenous plants have parallel-veined leaves, hence
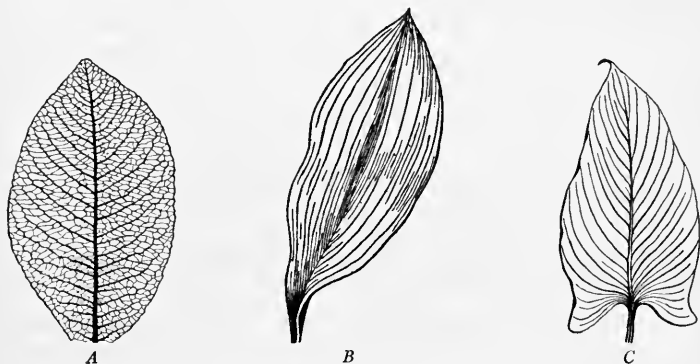

Fig. 64. — Venation of Leaves.
A, netted-veined; B, C, parallel-veined.

the leaf venation forms a ready though not a certain means of distinguishing these two great classes of plants.

Forms of Leaves. — Figures illustrating and naming the forms of leaves, their margins, bases, and apexes, are in the Appendix.

Structure of the Leaf Blade. — If a cross section of a leaf is examined under a high power microscope, the leaf will be found to be made up of cells of various forms. On both surfaces of the leaf will be seen a thin skin that covers the whole. This colorless skin, the *epidermis*, serves as a protection to the cells underneath. It is easily removed from some fleshy or soft leaves, like those of the houseleek. Children often suck the leaves of the live-forever, and thus loosen the epidermis.

Just under the epidermis, on the upper side of the leaf,

will be found rows of regular-shaped cells somewhat closely packed together.

This surface being transparent is fitted to transmit

FIG. 65. — Magnified section of an Apple Leaf from its Upper to its Lower Surface.

I, intercellular spaces.

the sunlight. The cells on the underside of the blade are more irregular in shape and much less closely compacted. They do not fill the entire space, there being some cavities between the cells, called *intercellular spaces*.
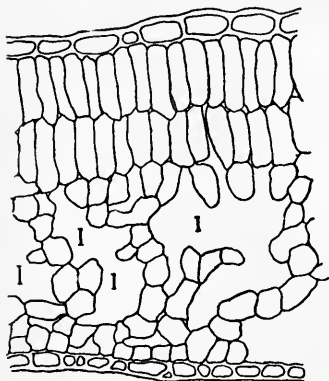
From some of the larger intercellular spaces there are openings through the epidermis to the outside air. These openings, or mouths, are called *stomata* (singular, *stoma*). Around each stoma are two liplike cells which have power to close the opening. They are called *guard* cells.

If the cells of the leaf are examined with a still higher power microscope, we shall see in all but those of the epidermis some small bodies that contain
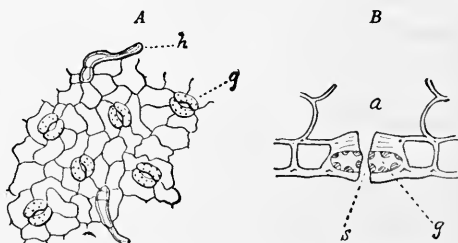

FIG. 66. — Stomata of an Oak Leaf (magnified).

In *A* the under epidermis has been removed to show stomata, *g*; *B*, a section of a stoma showing intercellular space, *a*; guard cell, *g*; and orifice of stoma, *s*.

green coloring matter. This matter is named *chlorophyll*, and is what gives the green color to the leaf.

Functions of Leaves. — This elaborate and peculiar arrangement of the cells of a leaf is an important feature of plant life.

Leaves do three kinds of work:

1. They furnish means for the evaporation of water brought up from the soil.

2. They take in air, utilizing the carbon dioxide during the process of food making and throwing off oxygen.

3. They change the substances received from the soil and from the air into plant food in a form capable of forming plant tissue.

Transpiration. — All parts of the plant that are exposed to the air evaporate water more or less rapidly in the form of vapor. This process is called *transpiration*.

Leaves, presenting as they do so much surface to the air, are particularly well adapted to promote transpiration. Under the influence of sunlight the stomata remain open during the day and thus present numerous openings for the passage of vapor into the air. A proper amount of transpiration is beneficial to the plant as it aids in the circulation of water to the extremities of the plant. On the other hand, when the air is very dry, transpiration goes on so rapidly that it retards the growth of the plant, and the water pressure of the cells is so reduced that the plant may shrink, or wilt.

It is an interesting fact that the stomata aid materially in regulating the amount of moisture transpired. When the cells of the plant are full of moisture, the guard cells about the stomata enlarge the openings into the intercellular spaces and transpiration is increased; on the other hand, when the cells have transpired more

water than is resupplied from the soil, the guard cells close the openings till the cells of the plant again become filled.

Quantity of Water Transpired. — The amount of water passing off by transpiration is enormous. To ripen an ordinary crop of small grain there passes out through the plants between three hundred and four hundred tons of water an acre. An ordinary hard wood tree will evaporate about as much water as is evaporated from the surface of a body of water equal to one third the total leaf surface of the tree. A grass plant has been found to give off its own weight of water every twenty-four hours in dry, hot, summer weather.

These large amounts of water are absorbed by the roots, carried through the plant and given off by the leaves because the plant food in the soil water is so diluted that the plant must take up great quantities of the water in order to get food enough for sustenance and growth.

Leaves take in Plant Food (CO_2) from the Air. —The food which the plant takes in through the roots consists entirely of mineral salts in solution. But this is not all the food that goes to the upbuilding of plant tissue. The minerals which go to make the plant substance will be found, after combustion, in the form of ashes. Nearly all of the plant tissue that passes off into the air during burning came from the air while the plant was growing. Air has mixed with it a substance absolutely necessary to the life of the vegetable world. This substance, known as *carbon dioxide* (CO_2), is a compound of carbon and oxygen.

The leaves of the plant are the great absorbents of carbon dioxide. It enters through the stomata into

the intercellular spaces and then into the cells. In these cells it comes into contact with the chlorophyll bodies. Under the influence of sunlight the chlorophyll can decompose the carbon dioxide into its elements, carbon and oxygen, and water (H_2O) into its elements, hydrogen and oxygen, and recombine these elements into new compounds, starch and two allied substances, sugar and oil. The starch formed is changed into sugar and then combines with the mineral nitrates, sulphates, and phosphates taken in

FIG. 67. — Diagram of the Formation of Starch.

through the roots, and forms a complex compound in a manner little understood. This is food for the protoplasm of the cells. When supplied with it in proper amounts, the cells multiply in all parts, or, in other words, the plant grows. These starchlike substances may be found in any part of the plant which has chlorophyll bodies, that is to say, in any part that is green, but the leaves are their greatest producers. It must be remembered that it is only in the presence of light that the chlorophyll bodies can perform this work of decomposition and recombination which results in plant food and consequent plant growth.
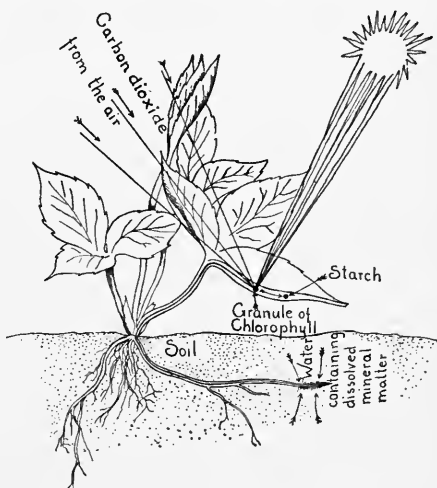
Note. — Take a green leaf from a plant at 6 o'clock in the afternoon. Soak it in alcohol to remove the chlorophyll, then put it into iodine and note that it turns dark purple, showing that starch is present. Take another leaf off the same plant at 5 o'clock in the morning and give it the same test, and no starch is revealed. The starch has been changed to sugar.

The Flow of Plant Food Downward. — This food, prepared almost wholly in the leaves of plants, must also pass to other parts of the plant if they are to grow. There is, therefore, in all growing plants a movement of the prepared food from the leaves to the stems and roots. To demonstrate this, cut a little notch through the bark and a little into the cambium layer of a tree. The uninjured cells around the edges of the cambium layer on the upper side of the notch will form a new layer of cells, but not on the lower side, thus showing that the cell food is coming from above. In exogenous plants the downward flow of plant food is through the inner layers of the bark.

Girdling Trees. — Because of this downward flow of the prepared food and upward flow of cell sap, it is easy to see what the effect would be of cutting a notch through the bark of a tree completely around it. The downward current of food prepared by the leaves would be checked and the roots would die for lack of food. If this is done after the unfolding of the leaves in the spring, they may remain green for some time because, as we have learned, the cell sap passes upward through the uninjured sapwood, so that the leaves receive nourishment for some time. If, however, the notch is cut through the sapwood also, the whole tree will soon die.

Food Storage and Uses. — Not all the food prepared by the plant is used in growth. The surplus is stored

in the form of starch, as in the potato, or sugar, as in the beet, or oil, as in cottonseed. Annuals, as corn, peas, oats, and beans, that is, plants that germinate, grow, bear flower and seed, then perish, all in one season, store their surplus food in the seed for its nourishment during germination. Biennials, two-year plants, store food during the first year generally in their large tap-roots, and the next year use this food in the production of flower and seed. Such are the carrot, beet, celery, cabbage, and parsnip. Perennials use only a part of their food for the production of flower and seed each year, and use the remainder for maintenance of life during the winter and leaf growth in the spring.

The crowning part of the plant is the flower, because it is the flower which produces the seed, the embryo, or germ, of the new plant.

Parts of the Flower. — The normal flower is made up of four parts: the *calyx*, a whorl of more or less united leaves, called *sepals*, usually of a green color, just underneath the *corolla*, which is the colored part of the flower (other than green), made up of more or less
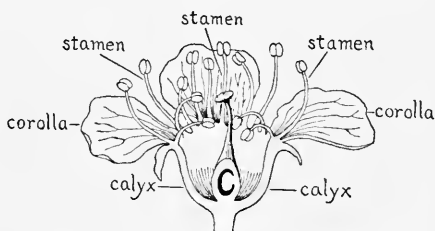

FIG. 68. — Section of a Cherry Blossom.

distinct parts, called *petals*. Around the inside of the corolla are slender, threadlike organs, called *stamens*, which are made up of the stalk, or *filament*, the enlarged top, or *anther*, and the yellow dust, or *pollen;* the center of the flower is occupied by a slender organ, called the *pistil*, which is also made up of three parts,

the enlarged base, or *ovary*, the supporting column, or *style*, and the flattened top, or *stigma*. In the ovary are one or more small bodies, *ovules*, which will
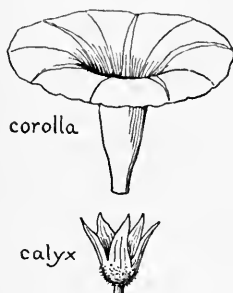

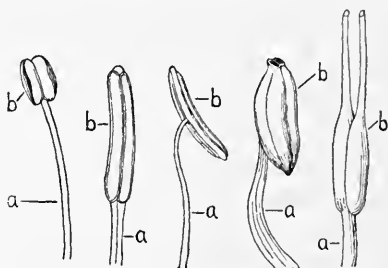FIG. 69. — Calyx and Co-rolla of Morning Glory.

FIG. 70. — Stamens.
a, filament; *b*, anther.

develop into seeds under proper conditions. Not all flowers are complete, sometimes one part and sometimes another being wanting.

Fertilization, or the process by which the ovule be-comes transformed into life-bearing seed, begins with the formation of pollen.
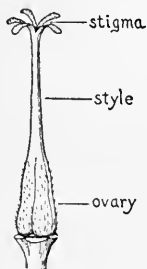

FIG. 71. — Pistil of Wild Gera-nium.

Each grain of pollen is a single cell con-taining protoplasm. During a certain period the pollen grains from the anthers readily cling to the surface of the stigma, which is generally made moist by the se-cretion of a sticky liquid. This process is called *pollination*. The pollen grains thus alighting send a slender tube through the stigma and style to the ovule in the ovary. Then, and not till then, occurs the trans-formation of the dormant ovule in the ovary into active life. This fertilized cell will now grow into a seed,

containing the embryo of a new plant and the food about it to nourish it during germination.

Pollination is brought about by insects, which carry the pollen on their bodies, by the wind, or by the force of gravity, as the anthers are usually higher than the stigma. Animals, birds, water, and man also play an important part in pollination.

It follows from what has been said above that a flower that has no pistil can produce no seed, nor does every flower that has a pistil necessarily produce seed. Pollination is not always followed by fertilization, for flowers that appear perfectly normal often fail to produce seed.

Perfect and Imperfect Flowers. — A *perfect* flower is one that contains both stamens and pistils, as in the apple. An *imperfect* flower may be *staminate*, having stamens only, or *pistillate*, having pistils only. Some plants, called *monœcious*, bear staminate and pistillate flowers on the same plant, as hickory, cucumber, and corn, while others, called *diœcious*, have the two kinds of imperfect flowers on different plants, as the hop.

Cross-pollination. — It is evident that pistillate flowers can produce no pollen, therefore if the ovule of these flowers is to be fertilized, it must be from pollen from another flower which bears stamens. This process is known as *cross-pollination*. The pollen may come from a staminate flower on the same plant or from one on a different plant of the same species or a plant of a different species. In the last two cases the fertilization results in a *cross*, or *hybrid*.

Artificial cross-pollination may be accomplished by first carefully clipping off the anthers of a perfect flower before the pollen is mature, then inclosing the

blossom in a sack of thin cloth or paper to prevent an accidental or undesired pollination. After waiting a period of from one to two days, the pollen of the desired blossom is applied to the stigma of the clipped flower by bringing an anther containing mature pollen in direct contact with it or by removing some of the pollen with a fine brush and transferring it to the stigma. The blossom should be inclosed again until the enlargement of the ovary shows that fertilization has taken place.

Planting for Pollination. — It follows from what has been said about the necessity of pollination to seed-production that the farmer must be careful in planting crops which bear imperfect flowers or there will be nothing to show in fruit and seed at the end of the season. All diœcious plants, like the hop and some varieties of the strawberry, must have pistillate and staminate plants in close proximity or no fruit will be produced. Many varieties of plums and pears require pollen of a different variety in order to be productive.

Flower Buds. — As a flower bud is a modified leaf bud, it is difficult to distinguish one from the other without careful observation. They may be on each side of the leaf bud, as in the peach, or may be formed on short, thick, crooked branches, called spurs, that are three or more years old, as in the apple and pear. In the apple, cherry, and peach the flower buds are usually thicker and more rounded.

Notes. — At what time in the life of the bud its character as a leaf bud or as a flower bud is determined is not definitely known. Sometimes the buds on the spurs of the apple tree all become leaf buds.

Checking the growth of a perennial plant about midsummer tends to

form flower buds for the next year's growth. As the dry season often occurs in midsummer, trees suffer a natural check in the reduced amount of moisture furnished. An abnormal check to growth may be given by pinching off the terminal buds or by cutting off the ends of the roots. After the tree is in vigorous growth in the spring, an otherwise barren tree may be forced to bear fruit by ringing, which obstructs the downward flow of the sap to the roots. The same result may be produced by violently twisting the branch which it is desired should bear or by simply bending it or tying it in an unnatural position. These harsh measures probably shorten the life of the tree by cutting off some of the normal food supply of the roots.

It is of interest to the farmer to know how to increase the growth of flower buds, inasmuch as his crop of
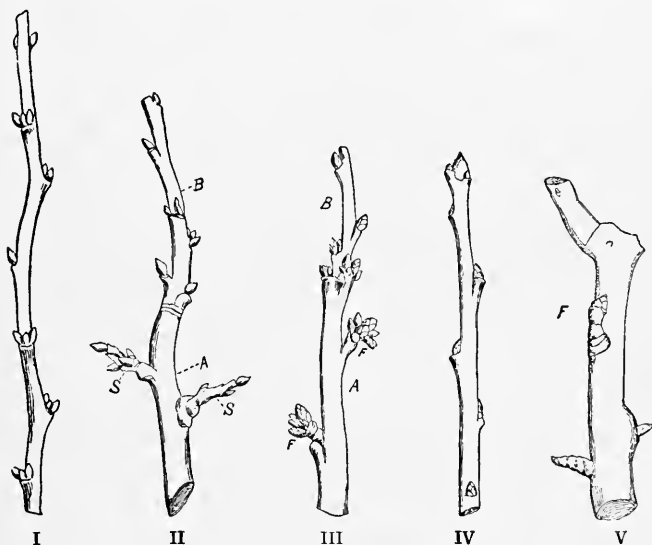

FIG. 72. — Buds.

I, Pottawattomie plum: in each group the central bud is a leaf bud; the two outer buds are flower buds. II, European plum; B, young wood; A, wood of preceding year; S, flower spurs. III, Morello cherry; B, young wood; A, wood of preceding year; F, clusters of flower buds. IV, apple: leaf buds. V, apple: F, flower bud.

fruit or seed depends wholly upon the number of flowers developed. This subject is not well understood by the botanist, but this general principle seems to be fairly well established: *Whatever tends to favor the accumulation of surplus food promotes flower-bud formation.* This means sufficient air and sunlight and protection of the foliage, sufficient plant food and moisture in the soil, and a moderate check to growth after a proper growth has been attained.

Methods of Plant Propagation. — Plant propagation is the multiplication of plants by natural or artificial means. Flowering plants are reproduced both naturally and artificially by seeds, rootstocks, stolons, suckers, bulbs, corms, and tubers. Flowerless plants are reproduced by *spores*, a peculiar cell structure with no embryo; but as only the lower orders of plants are thus propagated, the consideration of this method will be left until plant diseases are studied.

Seed Propagation. — We have learned that a seed is a plant in embryo with a supply of food formed by the parent plant either in the embryo or surrounding it. The whole is inclosed in seed coats.

As the farmer's crops depend so largely upon the germinating and growing power of the seed used, knowledge of how to select seed is of the greatest importance to him. There are many reasons why seeds do not germinate even when given the proper amount of heat, water, and oxygen. They may have been kept too long, they may have been stored where it was either too dry or too damp, they may have been gathered before complete maturity, they may have been frozen or chilled before being dried, or they may have been injured by insects or fungus growths. No one of these

defects is visible upon examination of the seed, therefore successful farmers generally make germination tests of their grains before planting in order to reduce to a minimum the chance of a poor yield.

Germinating Test. — A very simple apparatus for testing the germinating power of seeds may be made as follows: Place upon a plate two pieces of clean, rather heavy cloth, cotton flannel for instance, which have been dipped in water and squeezed
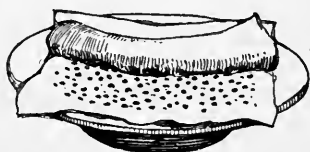

FIG. 73. — Seed Tester.

until only moderately wet. Place the seeds between the two layers of cloth, put another plate over the whole and keep it in a temperature of from 65 to 70 degrees. The percentage of germination may be found by dividing the number of seeds that sprout by the number placed in the tester.

As it takes only about a dozen ears of corn to plant an acre, and a test of each ear may be made by selecting a few kernels from different parts of the ear, it is comparatively easy to test all corn before planting.

A tester for this purpose may be made by filling a shallow box with sawdust, sand, or soil. This is kept moist and covered with a piece of cloth, preferably flannel, which should be rung out of water and kept moist. In making such test, it is advisable to devise some means of marking the kernels from the different ears to correspond with numbers placed on the respective ears in order that the percentage of germination for each ear

may be determined. The kernels in the first row at
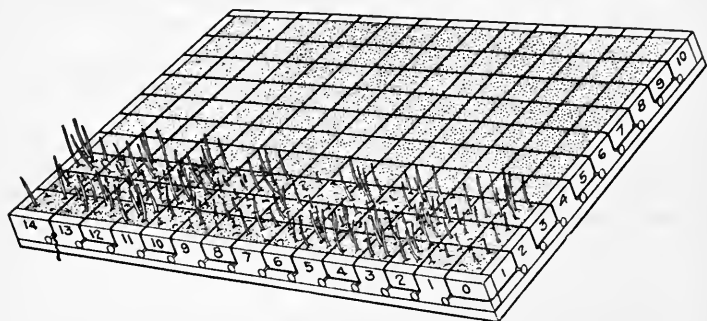the base of an ear of corn and those at the tip are likely

FIG. 74. — Sand Tray showing Corn Seven Days after Planting.
From Circular 96, Office of Experiment Station, U. S. Dept. of Agriculture.

to be poor in germinating power, so they should be
rejected. (See page 150.)

In general, it has been found that heavy, young, and
large seeds are the strongest seeds.

Impurities in Seeds. — The seeds of ordinary farm
crops, except corn, are likely to be mixed with dirt,
seeds of weeds and other plants, chaff, dead seed, and
imperfect seed. The smaller the seed, the more likely
it is to contain some or all of these impurities; thus it
is more difficult for the farmer to obtain clean, pure
clover and grass seed than clean, pure wheat and oats.
Cheap seed is likely to be the most expensive in the
end because the presence of part or all of these im-
purities will surely reduce the yield.

Treatment of Seeds before Planting. — Seeds are
sometimes soaked in water in order to soften the seed
coats and start germination. Seeds of many forest
and fruit trees are given a treatment known as *strati-*

fication before being planted. Alternate layers of seeds and sand are placed in a shallow box and the box is buried or set in a sheltered place covered with straw or leaves to the depth of a foot. The object of this is to soften the hard covering without stimulating germination. Many nuts, like those of the walnut, hickory, and peach, are allowed to freeze in order to crack their hard shells. Such seeds are sometimes stratified in boxes placed on the ground in sheltered places, or they may be merely placed in a pile on the ground with a light covering. Alternate freezing and thawing must be prevented in stratification or the life of the seed will become extinct. When once frozen, the seeds should remain so until settled weather. Upon being removed from stratification, they must be planted at once.

Seed Planting. — Goff gives four general rules for planting seed :

1. *The soil in which seeds are to be planted should be thoroughly crumbled*, because the seeds must have access to the oxygen of the air in order to germinate.

2. *Well-crumbled soil should be compactly pressed about the seeds* so that the seed case may come in contact with the moist soil particles at many points and thus absorb moisture.

3. *The soil should be moist, but not muddy*, because excess of water retards germination by restricting the supply of oxygen and reducing the temperature of the soil.

4. *Seeds should be planted no deeper than is necessary to insure the proper degree of moisture*, otherwise the young plant may expend too much energy in reaching the surface.

Propagation by Rootstocks, Stolons, Suckers, Bulbs,

and Corms. — In many grasses branches often lie along the ground or under the ground, take root at their nodes, and send up new plants. Such a branch is called a *stolon* or *runner* if it lies on the ground, and a *rootstock* if it lies under the ground. The strawberry,

FIG. 75. — Stolons of Black Raspberry.

black raspberry, and white clover are propagated by means of stolons, and Kentucky blue grass by rootstocks. Bermuda grass is propagated by rootstocks and stolons. These methods of reproduction enable plants to perpetuate themselves after the original plants from seed are dead. The dense sod of lawns and pastures is due to propagation by stolons and rootstocks.

A *sucker* is a branch which springs from a parent stem underground where it makes roots of its own, then farther on rises above ground into a leafy stem and becomes an independent plant whenever the connection with the parent plant is broken. The rose, the blackberry, and the red raspberry are propagated by suckers.

Note. -- Suckers appearing at the base of the same stalk or in the axils of the leaves of the tobacco plant are not used for propagating plants.

Bulbs have been defined on page 134. They often divide naturally into two or more parts or may be so divided artificially, each of which parts may become another plant. Bulblets often form around the parent bulb, and these may be used to propagate.

A *corm* is like a bulb in outside appearance, but it is solid throughout and made up of leaves like the onion or lily bulb. Small corms develop much as do bulblets, and may be used in the same manner. Gladiolus and Indian turnip are good examples of corms.

Artificial Propagation. — Many of the methods of propagation just described are either natural or artificial, but the following are entirely artificial, having been developed by man to increase reproduction.

Cuttings. — A *cutting* is a detached portion of a plant placed in soil or water to produce a new plant. The part detached may be a root, a stem, or even a leaf, but the chances of successful growth are better if the younger, matured growths are used and the part contains one or more buds.

One end of the cutting of a stem is usually placed in a box of sand, in the soil, or in water, and if the proper amount of heat

FIG. 76. — Cuttings.

and moisture be supplied, roots will first be developed and then the slip will put forth new branches, leaves, flowers, and fruit. Root cuttings are generally buried in the sand or the soil, where, if healthy, they will

send up a stem and in time will become a new plant
with the characteristics of the parent plant.

Nearly all plants can be propagated by cuttings, but
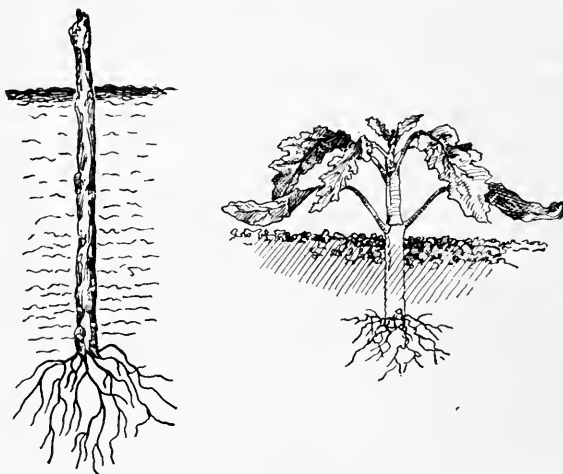such propagation is not practicable in all cases.   Cur-

Fig. 77. — Rooted Cuttings.

rants and grapes are commonly increased in this way,
as are willows and poplars.

Cuttings may be made from plants in the autumn and
stored during the winter if kept in a place sufficiently
moist to prevent the plant's losing water by evapora-
tion.   Damp sawdust or sand will usually accomplish
this.

Note. — As frequent changes of temperature are unfavorable to the
development of cuttings, nurserymen have devised what is known as a
cold frame to confine the heat of the ground or shut out the heat of the
sun when necessary.   This consists of a bottomless box, higher on
one side than on the other, and covered with glass or muslin painted

with linseed oil to render it waterproof. The frame is placed so as to have a south slope. Occasionally the sun's rays are so hot that a covering must be thrown over the glass if glass is used, but if muslin or paper is used, none is necessary. The frame must also be additionally protected in freezing weather.

A *hotbed* is like the cold frame except that it has heat beneath it, this heat being produced by the fermentation of manure, leaves, or tan bark used as a foundation. This foundation may be put into a pit two or two and one half feet deep dug in
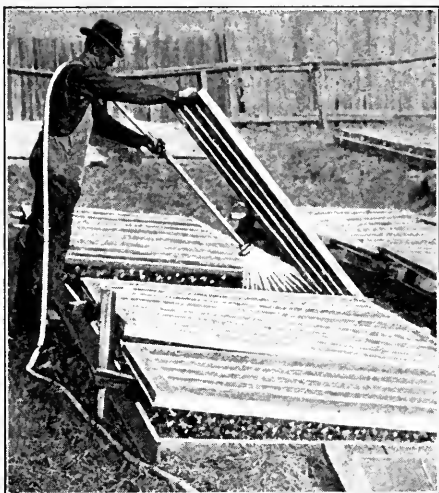

Fig. 78. — Cold Frames.

the ground or may be placed on top of the ground. The cuttings
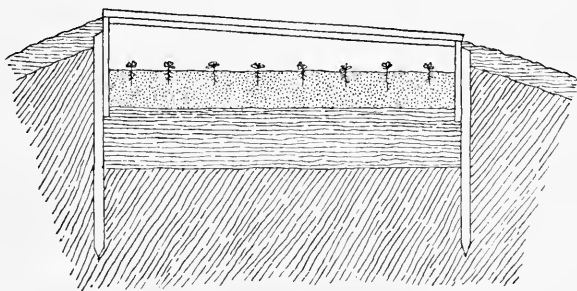

Fig. 79. — Section of a Hotbed.

require a temperature of about 90 degrees, and as the fermentation sometimes produces a much greater degree of heat than this, care

must be taken to cool off the hotbed, in order that the slips may not be destroyed.

Ringing. — Sometimes cuttings set out in the ordinary way are slow in forming roots. If it is known that any species is thus slow, a good remedy is to ring the branches from which cuttings are to be made; that is, make a slight groove around the stem just below a node, in July or August. This will induce the storage of food above the groove and the formation of a callus on the upper side of the ring. In the fall the cutting should be made just below the ring, and the slip set out in the ordinary way.

Root Cuttings. — Short cuttings, from one to three inches, may be made successfully from the roots of some hardy plants, like red raspberry, plum, and blackberry, if made in autumn and stored in boxes with moist sand. In general they thrive better if kept in a cool place, but sometimes they need a little higher temperature towards spring to induce the formation of roots and buds. They require very shallow planting, from one half to three quarters of an inch, in finely crumbled soil. Sometimes they need shading and watering during early growth, that is, if the weather is warm and dry.

Layering. — By *layering* is meant the bringing of a branch into contact with the soil, covering it slightly, thus inducing it to form roots and shoots which constitute an independent plant, the branch meanwhile remaining connected with the parent plant. This method of propagation is often used with woody plants which do not root readily from cuttings. Grape vines may be stretched along the ground and buried in a shallow trench or may simply be covered at certain intervals: in either case roots will be sent down and

branches thrown up at various points, several new plants being thus formed when the vine between is cut.

Plants which send up a large number of stems from a single root may be layered by filling up the soil in a
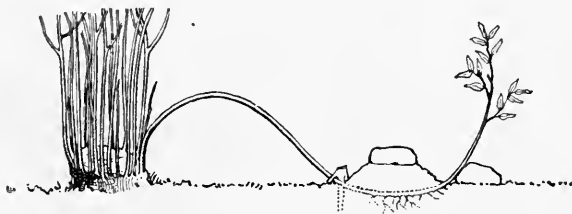

FIG. 80. — A Rooted Layer.

mound around the bases of the stems. New roots are thus sent out by each stem, and when fully developed, the parent plant may be separated into several new plants.

Grafting consists in placing in close contact the cambium layer of a severed portion of one plant and the cambium layer of the root or stem of another plant. The portion cut from one plant for grafting to another plant is called a *scion*.

Time for Cutting Scions. — Scions of fruit trees are cut just after the fall of the leaves in autumn. They are then made into bundles and buried in moist sand, and kept in a temperature that is above freezing point, but below growing point. Sometimes good results are obtained by cutting the scions in the spring and grafting them at once, that is, if cleft grafting is to be employed.

What Grafting will Accomplish. — While it is true that the scion will unite with another plant, the *stock*, it must not be thought that the graft loses its charac-

teristics by this union. If a Northern Spy scion is grafted on the stem of a Jonathan apple tree, the branches that grow from it will always bear Northern Spy apples, although the nourishment comes through the Jonathan roots and stem, and the branches of the stock will continue to bear Jonathan apples.

It is thus apparent that one of the things grafting will accomplish is to make a plant of inferior variety bear fruit of a superior variety.

Another useful result of the process is to multiply plants that do not multiply well from seed, for example, our common fruits. Trees may be made smaller by grafting from a smaller variety.

It is a well-known fact that seedlings take many years to come to the flowering and fruiting stage. If it is desired to improve the variety of any certain fruit, grafting on a seedling grown for this purpose will hasten the formation of flower and fruit.

The symmetry of a tree that has broken branches may be restored, and defective branches be replaced by grafting.

Some fruit trees are liable to be injured in the root or trunk by special insects which do not infest other fruit trees. By grafting, for instance, a peach scion on a plum stock, peaches may be grown without injury from the insect that infests peach trees.

To summarize, grafting makes it possible:

1. To change the variety of a plant, substituting a desirable plant for an undesirable;

2. To hasten the fruiting of seedlings;

3. To multiply plants that do not multiply well from seeds;

4. To render defective trees symmetrical;

5. To save injured trees;

6. To change the size of trees;

7. To avoid injury and loss from insects which especially infest some trees.

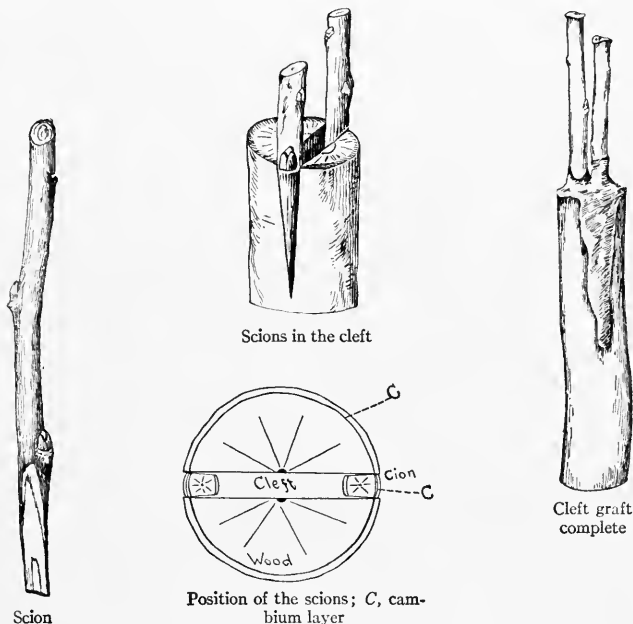**Cleft Grafting**. — This method is adapted only to large trees of which it is desired to change the variety.

Scions in the cleft

Scion

Position of the scions; *C,* cambium layer

Cleft graft complete

FIG. 81. — Cleft Grafting.

A branch of the stock to be grafted from one to one and one half inches in diameter is sawed off, care being taken not to loosen the bark of the stub, which is then split with a chisel or grafting tool. The opening is then spread with a wedge and the scions inserted. These scions should be new growths of the previous season,

having two or three buds. The lower end of the scion
must be wedge-shaped, with the outer edge thicker.
This last is important, because if the inner edge were
thicker, the outer edge, where the living cambium is,
would not touch the cambium layer of the stock, and the
scion would die. It must be remembered that these
two living layers must be in close contact or no union
will take place.

All cut surfaces should be covered with grafting wax,
which is made as follows: Melt and pour into water
four parts of resin, two of beeswax, and one of tallow;
as the mixture
cools, work it with
the hands until it
is of a yellowish
color. Make it into
rolls and wrap them
with waxed paper
to prevent them
from sticking to-
gether.

Whip Grafting. —
This method is
much used in graft-
ing on stems when
the scion and stock
are about the same
size. In this case
both are cut with
a slanting surface,
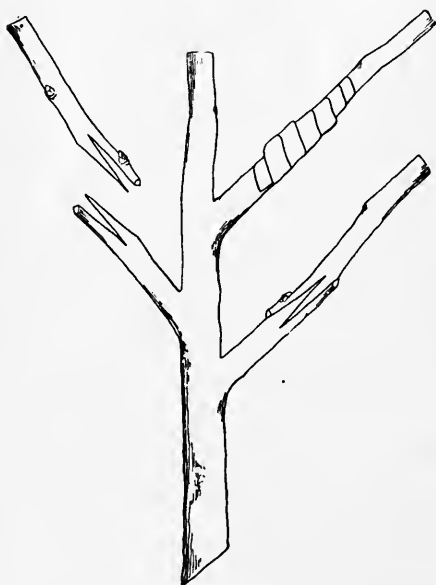from three quarters

FIG. 82. — Whip Grafting.

of an inch to an inch long. The stock has a slit, or
tongue, made in it down lengthwise from the cut, and

the scion has a smaller one. The two are then pressed together, the tongue of the scion fitting into the slit of the stock, and the two tied tightly together with waxed cord, cloth, or paper.

Root grafting by this method can be done indoors in winter and is therefore an economical method for the farmer. The stocks are usually seedlings of one or two years' growth, dug in autumn and stored as recommended for scions on page 159. When ready for grafting, the roots are washed and pieces cut from two to six inches long, stock and scion being about the same length. After grafting as described above, the grafts are packed away in moss, sawdust, or sand in a cool cellar, about 40° F., and planted in the spring.

Notes. — Grafting cord is made by soaking balls of common wrapping twine in melted grafting wax.

Grafting paper is made by painting thin wrapping paper with melted grafting wax. Spread the paper on a heated board and apply the wax melted sufficiently to spread easily. Thin muslin or calico is often used instead of paper.

Budding. — This method of plant propagation is increasing in favor because of its economy, inasmuch as only one bud is needed for a scion, whereas in cleft or whip grafting there must be two or three to insure success. On the other hand, it is more expensive in stocks because a seedling is required for each scion, while in root grafting two or three can be made from one seedling.

The bud is taken from the current season's active growth, that is, from July to September. In cutting the bud it is best to remove with it a portion of the

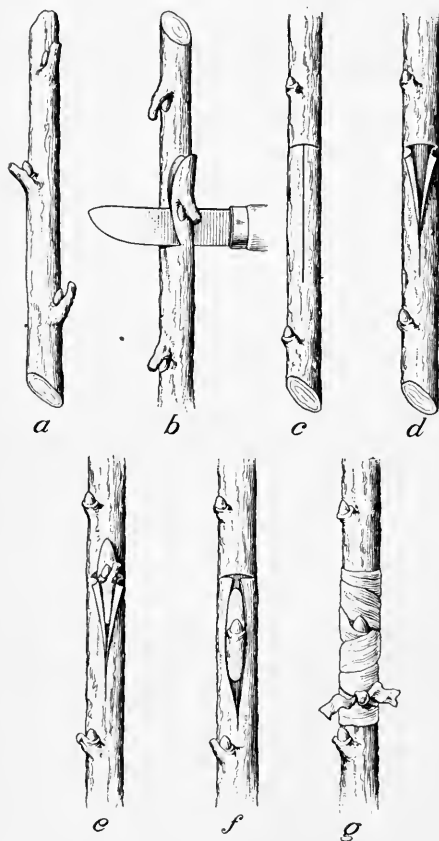bark to serve as a handle in pushing the scion into the

stock. The stock should have a stem about three eighths of an inch in diameter, which means two seasons' growth of the apple or pear and one of the peach; a T-shaped cut is made in the cambium layer of the stock, the bark loosened a little, and then the bud is inserted and tied firmly in place above and below the bud. Care must be taken that the bud is fresh, moist, and the growing point uninjured.

The ligature binding it in place must be removed as soon as the union is accomplished, in about ten days, in order

FIG. 83. — Steps in Budding.

a, twig having suitable buds to use; *b*, method of cutting off the bud; *c*, how the bark is cut; *d*, how the bark is opened; *e*, inserting the bud; *f*, the bud in place; *g*, the bud properly wrapped. (Cummings.)

that the tree shall not be girdled by it. (See page 144.)
Just as soon as the bud begins to grow, the top of

the stock must be cut off in order to stimulate the growth of the bud.

Ring budding is sometimes performed in the spring on thick-barked trees, like the hickory. This consists in removing a narrow strip of bark nearly around the stock and inserting therein a strip of the same size containing a bud, then binding it in place.

Plant Breeding. — Creative force manifests itself in an infinite variety of forms and qualities, no two plants, no two animals being exactly alike, either in appearance or in characteristics. This lack of uniformity in the individual plants in a field, for instance, is responsible for a low yield of inferior quality, for if all of the plants in the field were uniformly of the same type as the best plants, the yield and value of the crop would be greatly increased and the expense of handling the crop would be reduced, thus doubly adding to the grower's profits.

Problems of Plant Breeding. — One of the most important and most difficult problems the farmer has to solve is how to breed plants so as to bring up the average of the crop to that of the best individual plants. In the case of those plants which are partly or wholly self-fertilized, that is, fertilized by pollen from the same flower or plant, such as wheat, oats, barley, and tobacco, the problem is not so difficult to solve as with plants that depend upon cross-fertilization, such as corn and hemp.

The problem presents three phases:

1. How can variations from the parent type be produced?

2. How can selections of the best types be made?

3. How can the new types be made to reproduce

their characteristics and be kept from reverting to the inferior, original type?

FIG. 84. — Plant-breeding Plots (Minnesota Experiment Station).

It will be seen that the plant breeder is really trying to do two directly opposite things: first, to induce *variation* and thus improve his variety; second, to

induce *uniformity* after he has secured the variation he wishes, that is, he is trying to fix the variation. Variation can in some cases be induced:

1. By culture. Change of food and climate will work changes from the parent plant little short of marvelous.

2. By growing seedlings. This method is used with plants which have usually been propagated by budding, grafting, or division (like dahlias). Characteristics of the parent plant are more variable than those of varieties grown from seed, therefore the young seedlings will show differences. Desirable individuals among these may be chosen for fixing.

3. By cross-pollination. (See page 147.) This method will work changes from the parent type nothing less than wonderful. Burbank has secured some marvelous results largely through this method. The individual plants produced from the two parent plants are not exactly like either, neither are they like each other. Some of them resemble one parent in a marked degree and some of them the other. It is quite within the probabilities that scientific breeding by cross-pollination will be able to produce individuals that have *only* the best characteristics of each of the parent plants and that the seeds of these individuals may be used to perpetuate the variety.

To insure the best results, the plant breeder should have clearly in mind the characteristics which he desires to secure in his new variety, and then select the two parents with care.

A wise selection is the plant breeder's most potent factor in securing uniformity and thus improving his crops. This means the rejection of many individuals and the retention of a few desirable ones from which

to breed. The planting of seed from a large squash is not necessarily making a wise selection unless that squash grew on a vine that bore more than one large squash. The unit of selection should be the *parent plant*, not one individual.

Experiments have shown that there are two possible ways to fix a variation:

1. By propagating the plant by budding or grafting (pages 159–165), instead of from the seed. This method is practicable for trees, shrubs, fruits, potatoes, and many flowering plants.

2. By constant selection of seed toward the desired type. This method is more or less practicable with the grains and garden vegetables. For instance, if it is desired to secure an especially early variety of corn, we must save all seed from a single plant that early matured large, strong ears, and plant them the following spring. Not all the plants from these seeds will mature even as early as the parent plant, but probably a few will. The seed from these few should be saved and planted the next spring. Continuing this process for several seasons will in time fix a variety of early corn. It must not be thought that the variety is thus permanently fixed, for the tendency is for such plants to run out, that is, lose their distinctive characteristics.

The only way to know whether improved varieties will transmit their superior characteristics to the next generation is to make tests. If, for instance, varieties of corn have been produced which have full, strong ears, a few should be planted from one ear of each variety and the yields compared. In no other way can it be determined whether selected individuals will reproduce their desirable characteristics.

Selecting and testing to see which plants are best able to transmit their good qualities have done much to improve our farm crops, the most notable improvement being in the sugar beet, corn, barley, tobacco, apple, and potato. The same methods applied to wheat, oats, and grasses will produce like beneficial results.

One general rule must be followed in all plant breedings: *Choose the best, then test the yielding and transmitting power.*

Note. — Experiment stations do systematic work in plant breeding, and continue to establish plants of certain desirable characteristics through continuous selection year after year. To facilitate the work of breeding small grains, the plantings are made in plots of ground holding a definite number of plants. These plots are called *centgener* plots. When the grain is harvested from these plots, it is often desirable to inclose each bundle with a cloth cap so that none of the grain may be lost through storms, birds, or insects. These caps may be seen in the foreground of the picture showing a part of the plots of the Minnesota Experiment Station.

Plant Families. — There is such a great number of different kinds of plants that to study each kind separately would take more time than would be possible in the life of any man. Botanists have noted certain general characteristics that are common to certain groups of plants. These common characteristics make it possible to divide the vegetable kingdom into great divisions, classes, orders, families, genera, species, and varieties. By learning the characteristics of a single family or order, he learns certain general things about all the plants that belong to that family.

All vegetable life consists of four great divisions, — the thallus plants, the moss plants, the fern plants, and

the seed plants. The first three divisions include such plants as are represented by bacteria, molds, mildews, rusts, mushrooms, yeasts, mosses, and ferns. Many of the plants in these divisions are of great importance in agriculture, but, except mushrooms, none of them is raised by the farmer as a food crop.

Seed plants include all the great families that go to make the crops of the farm.

They may be divided into two subdivisions. Those having their ovules naked, that is, not inclosed in an ovary, are called *Gymnosperms*. The pine family, including a large number of the evergreens, belongs here.

Those having their ovules inclosed in an ovary are called *Angiosperms*. The Angiosperms are again divided into two classes, depending on the number of cotyledons, or seed leaves, in the seed. Those Angiosperms having one cotyledon are called *Monocotyledons* or *Endogens*. Besides being distinguished by having but one cotyledon, monocotyledons have usually parallel-veined leaves and usually have parts of their flowers in threes, never in fives. The corn plant is a good illustration of a monocotyledon.

Note. — An earlier classification of plants makes two great divisions:

I. Cryptogams $\begin{cases} \text{The algæ and fungi and their allies.} \\ \text{The liverworts and mosses.} \\ \text{The ferns, horsetails, and club mosses.} \end{cases}$

II. Phanerogams   The seed plants.

Angiosperms having two cotyledons in the seed are called *Dicotyledons* or *Exogens*. They usually have netted-veined leaves, and the parts of their flowers in fives. Each of these subclasses is divided into numerous families or orders, about one hundred of which are

usually described by botanists. Most of the plants of special interest to farmers may be included in eight families whose characteristics may be very easily learned.

The general classification of the vegetable kingdom, as far as given, is graphically represented below:

Vegetable Kingdom	I. Thallophytes, or thallus plants	Algæ Fungi			
	II. Bryophytes, or moss plants	Liverworts Mosses			
	III. Pterido-phytes, or fern plants	Ferns Horsetails Club mosses			
	IV. Spermato-phytes, or seed plants	Subdivision I, Gymnosperms, or seed plants with naked ovules, such as pines, spruces, and many other evergreens	Class 1, Monocot-yledons or En-dogens	Families 1. Gramineæ, grasses and cereals	
		Subdivision II, Angiosperms, or seed plants with inclosed ovules	Class 2, Dicotyle-dons or Exo-gens	2. Cruciferæ 3. Rosaceæ 4. Leguminosæ 5. Umbelliferæ 6. Solanaceæ 7. Compositæ 8. Cucurbitaceæ	

Gramineæ, or Grass Family. — This is a very large family, the only one in the endogenous class that is of great importance to the farmer. It includes not only all the grasses, but also all the cereals, which make up such a large part of the farm crops. Sorghum, broom corn, Kaffir corn, and the millets are also included in this family.

The June grass, or Kentucky blue grass (Fig. 85), may be taken as typical of the family. Its roots are fibrous and spreading. Its stem, called a culm, is hollow, jointed, and enlarged at the joints. The leaves

are parallel-veined and inclose the lower part of the
stem, as in heath. The flowers are on the end of
the stem in a cluster, whose branches are branched again. The flowers may be contracted into a long head, as in timothy; such a form is called a *spike*. The flowers are collected into little clusters called *spikelets*. With a small magnifying glass the spike may be easily analyzed. At the base are two chaff-like bracts, called *glumes*, rising above which are four flowers. If each of these flowers is observed

FIG. 85. — June Grass.

1, spikelet with two glumes and four flowers; 2, a single flower; 3, ovary and feathery stigmas; 4, ripe kernel inclosed in the two pales.

carefully, it will be seen to consist of two chaffy bractlets, called *pales*, one a little above the other (Fig. 85, 2), then three stamens, and lastly an ovary with two feathery stigmas (Fig. 85, 3). The ovary ripens into a one-seeded grain.

These parts may be seen more distinctly in the oat plant. Each member of the great grass family differs

from every other member in one or more ways, but they agree generally in the following characteristics :

(*a*) Plants endogenous with fibrous roots ;

(*b*) Stems hollow or pithy between the solid joints ;

(*c*) Leaves alternate ;

(*d*) Flowers in spikelets with alternate glumes and pales ;

(*e*) Ovary with two and sometimes three plumelike stigmas and one ovule ;

(*f*) Stamens usually three.

Cruciferæ, or Mustard Family. — This family is represented by some of our most important garden vegetables, including the cabbage, turnip, rutabaga, radish, and horse-radish. It in-

FIG. 86. — The Wild Mustard.

An individual flower and a seed pod appear at the left, and at the lower left-hand corner is shown a flower.

cludes also water cress, mustard, peppergrass, shepherd's purse, and French weed.

All the flowers of the plants in this family are arranged along the stem, as in the currant. This form is called a *raceme*. The lower flowers are the older and often develop ripened fruit while upper nodes are lengthening and developing new flowers. The seeds are formed in a two-celled pod, called a *silicle* when short, and a *silique* when long, as in the mustard.

The flowers have four sepals and four petals ar-

ranged so as to form a cross, hence the name *cruciferæ*.

The following characteristics are common to all members of the family:

(*a*) The flowers arranged in racemes, with the lower flowers the older;

(*b*) Flowers cruciform;

(*c*) Stamens six, four long and two short;

(*d*) Pod, two-celled;

(*e*) Fruit a *silicle* or a *silique*.

Rosaceæ, or Rose Family. — This important family has among its plants herbs, shrubs, and trees. Here are found the pear tree, the apple tree, and the crab-apple. Berries are represented by the blackberry, raspberry, thimbleberry, shadberry, and strawberry. The stone fruits include the peach, the plum, and the cherry.

The plants of this family have regular flowers with calyx and corolla each of five parts. The stamens, which are numerous and distinct, arise from the calyx. The flowers may have one or many pistils. They may be distinct, or they may be united and combined with the calyx, as they are in the apple.

The following are the common characteristics:

(*a*) Flowers regular, that is, one sepal like another on same flower and all petals alike on the same flower;

(*b*) Corolla in five parts;

(*c*) Stamens numerous and inserted on the calyx.

Leguminosæ, or Pea Family. — The common garden pea is a characteristic member of this large and important order. Its importance is due not only to the plants that furnish foods rich in nitrogen, but also to the fact

that all the legumes are able through the bacteria in the tubercles on the roots to fix free nitrogen, that is, to make a nitrate of the nitrogen in the air. The most familiar of the legumes are beans, peas, lentils, peanuts,
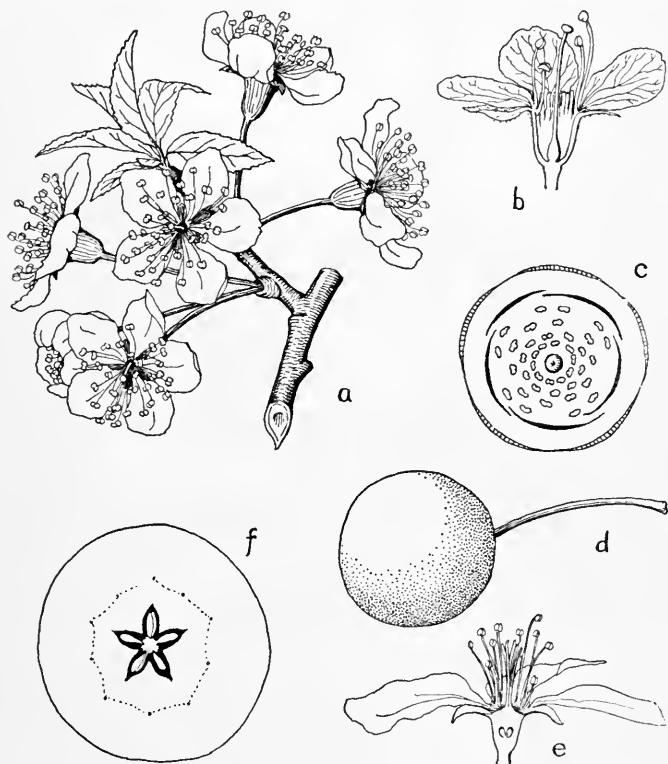

FIG. 87. — Plum and Apple.

a, plum blossoms; *b*, section of flower; *c*, diagram of flower; *d*, plum; *e*, section of apple blossom; *f*, section of apple.

clovers, alfalfa, and the locust tree. Some not so familiar are gum arabic, tolu, tragacanth, indigo.

licorice, senna, logwood, Brazilwood, and sensitive plant.

The corolla of a few of this family is regular, but all the plants that are valuable for food have papilionaceous

FIG. 88. — Garden Pea.

1, the corolla displayed; 2, the diadelphous stamens; 3, the ovary dissected, and the peculiar style and stigma.

(butterfly-shaped) corollas similar to that of the pea. They have five irregular petals. The upper, or odd, petal

is larger than the others, usually turned backward or spreading; the two side petals, called the wings, are outside of the two lower petals, which are often joined to form a keel. There are ten stamens, nine of which are united

FIG. 89. — Wild Parsnip.

a, umbel; *b*, leaf; *c*, flower; *d*, section of fruit; *e*, petals; *f*, *g*, stamens; *h*, pistil; *i*, diagram of flower.

by their filaments, while the tenth is separate and free. This condition is called diadelphous, that is, in two sets.

There is a simple free pistil which becomes a legume, or pod.

The characteristics of this family may be summarized as follows:

1. Papillionaceous corolla;
2. Ten diadelphous stamens;
3. One simple pistil becoming a legume or pod.

Umbelliferæ, or Parsley Family. — Many of the common garden plants and some common weeds are representatives of this large family. The carrot, parsnip, celery, parsley, and chervil are used for food. Anise, caraway, coriander, dill, and cummin furnish odors and flavors.

The chief characteristic of this family is, as its name suggests, the collection of its flowers into an umbel; that is, the flowers are on the ends of the short stems, or pedicels, which spread out from the end of the main stem like the rays of an umbrella.

Umbel-bearing plants have:

1. Hollow stems;
2. Flowers arranged in umbels;
3. Flowers in fives as to parts of corolla, calyx, and number of stamens.
4. Pistil two-ovuled and two-styled.

Solanaceæ, or Nightshade Family. — Although the members of this family have certain characteristics that bring them together in one family, the members differ so radically in many other ways that it is difficult to think of them as belonging together. From ordinary appearance one would scarcely think that there was a very close relationship between the sandbur and the potato, or between the tobacco plant and the tomato, yet their likenesses group them in this family. Here

also belong the jimson weed, the ground cherry, and the henbane. The foliage is rank-scented, the fruits are mostly narcotics, often very poisonous, though some are edible.

The general characteristics of this family are:
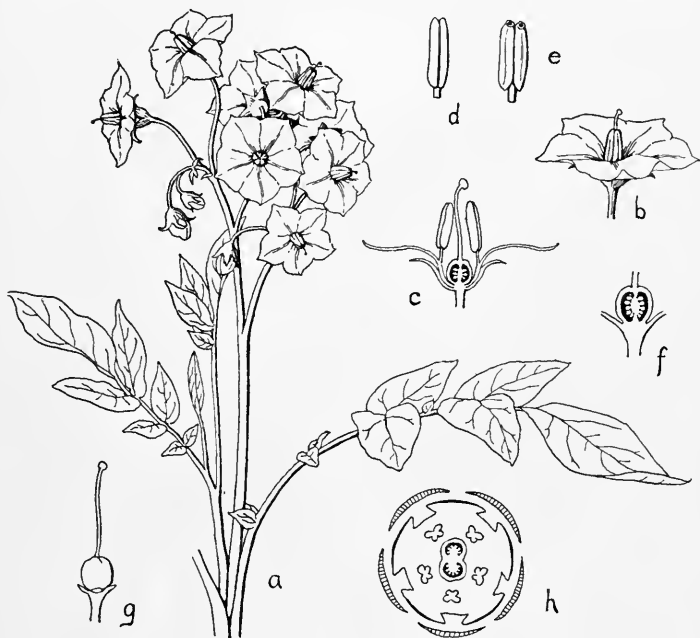
1. Flowers regular, five-parted, corolla wheel-shaped;

FIG. 90. — Potato Plant.

a, flowers; *b*, flower; *c*, section; *d*, *e*, anther; *f*, section of ovary; *g*, pistil; *h*, diagram of flower.

2. Five equal stamens inserted on the calyx;

3. Style and stigma single, the fruit a two-celled, many-seeded capsule or berry.

Compositæ, or Aster Family. — About one tenth

of the flowering plants of the world are included in this great family. Conspicuous among them are the asters, the goldenrods, the sunflowers, the dandelions, and the thistles. The most useful plants of this family are the lettuce, salsify, chicory, saffron, and the plant the pulverized heads of which furnish the Persian insect powder.
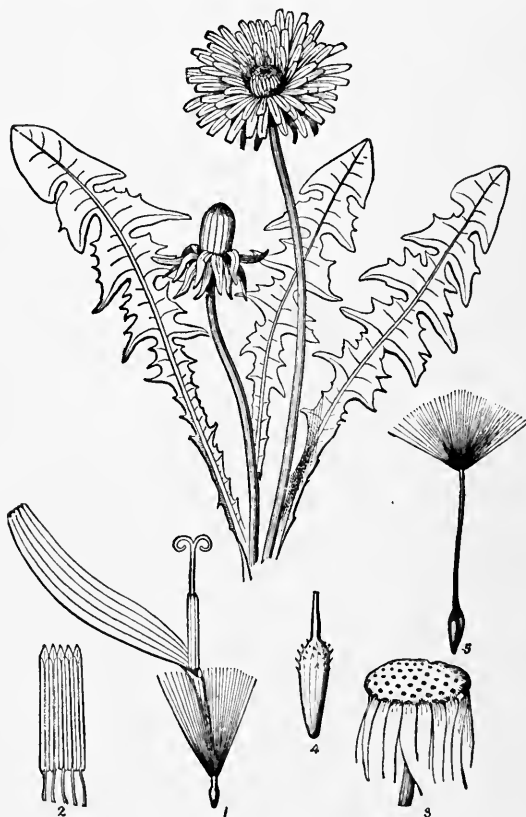
Fig. 91. — Dandelion.

1, a single flower; 2, stamens; 3, the receptacle and involucre; 4, a fruit; 5, a fruit with its pappus.

The chief characteristics are as follows:

1. Flowers collected into a head;
2. Corolla of five united petals (gamopetalous);
3. Five stamens united by their anthers into a tube;
4. Two stigmas, one style, one-ovuled ovary.

Cucurbitaceæ, or Gourd Family. — This family includes the squash, the pumpkin, the cucumber, the muskmelon, the watermelon, the citron, and the gourd.

The plants are mostly herbs with tendrils, the flowers distinguished by having stamens and pistils in separate flowers. These may be on the same plant (monœcious), or the pistillate flowers may be on one plant and the staminate on another plant (diœcious).

Besides the above characteristics, the gourd family has the following:

1. Five stamens united by their anthers;
2. Two or three stigmas, seeds large, usually flat.

CHAPTER IV

ECONOMIC PLANTS

THE forms of vegetation that most interest the agriculturist have economic value, that is, they minister to the needs of mankind by furnishing food, directly or indirectly, clothing, shelter, or medicine. These economic plants may be classified upon different bases. A convenient classification is the following: cereals; sugar plants; oil plants; fiber plants; stimulants, medicinal and aromatic plants; grasses; legumes; vegetables; fruits; tubers; roots.

CEREALS

By far the greater part of the food for the human race comes from the grain-bearing plants, or cereals, so-called from Ceres, the name the Romans gave the goddess of the harvest. The cereals commonly grown are wheat, corn, oats, barley, rye, rice, and buckwheat. All these plants, excepting corn and buckwheat, have certain similar characteristics of growth, — their roots are fibrous, their stems are hollow and jointed, and their leaves are long and narrow, — characteristics which they possess in common with other grasses.

It is also characteristic of these cereals to thrive best from shallow planting, one inch or less below the surface. A peculiarity of their root and stem forma-

tion is that the first section of the stem forms just below the surface of the ground, and fibrous roots grow from the same point. The stem grows above the ground and the leaves open in the air and light, whereupon other roots form at the first joint of the stem, very near the surface of the ground. These increase in number and spread very rapidly. When the plant has enough of these to hold it firmly in place, the section of the stem below them and also the first roots formed die and by their decay add humus to the soil. If a plant of this family is vigorous, it will, in addition to the secondary roots sent out; also develop a number of stems at the first joint, thus making a multiple plant with increased seed-bearing capacity. This latter process is called *stooling*. Too deep planting hinders stooling. Grain in rich, moist soil, if not too thickly sown, will in cool weather stool rapidly and thus bring a large yield from few seeds.

Wheat is the most important food of the human race, not that it is the most nutritious, for it is not, but it is sufficiently so to make it, with its palatable quality, and the great variety of forms it can be made to assume, the most desirable of the food stuffs. Waldo Brown says: " In many respects wheat seems to be the most important crop the farmers grow. Its importance is due to the following facts:

" 1st. It is a crop which always commands the cash, and is always in demand. In speaking of the value of other crops or of investments, it is a common expression with farmers that ' it is as good as old wheat in the mill.'

" 2d. It divides the work so that a single team can do much more on a farm where wheat and corn are

grown in about equal proportions than where corn is the sole or principal crop.

"3d. It can be successfully grown on rolling lands, which, if continuously cultivated in corn, would soon be ruined by washing.

"4th. It gives an opportunity to rotate with clover which, while occupying the land, furnishes plant food for successive crops, and is thus almost an essential in any good rotation.

"5th. It can be easily stored. There is little risk of injury from dampness, and almost no loss from shrinkage.

"6th. It furnishes the farmer a large bulk of straw, which can be utilized for food, bedding, shelter, and as an absorbent for liquids which would, without it, on many farms be wasted.

"7th. As wheat is exported to a large extent, and can be held for one or more years if desired, it is less subject to fluctuations in price than many other farm products, and is not so likely to be depressed by an unusually heavy crop."

Production of Wheat. — Europe produces annually twice as much wheat as North America, not because of having twice as much land devoted to the culture of the grain, but because many European farmers, by better cultural methods and the use of commercial fertilizers, raise twice as many bushels an acre. The average annual crop of the world is about three and one half billions of bushels, most of which is eaten by the human race, it being too expensive to use as food for other animals. Canada and Argentina are opening up large areas rapidly and increasing the wheat yield of North and South America.

Kinds of Wheat. — There are two main classes of wheat based on the time of sowing, namely, *winter* wheat and *spring* wheat. Two other terms are used to express types of wheat, *hard* wheat and *soft* wheat, both winter and spring wheat having varieties of each type. Then, again, there are many varieties of each class based on color, awns, chaff, and the like. It is difficult to determine with accuracy the different varieties as they are growing in the field, and it is often more difficult to determine the varieties by looking at a sample of the grain.

The heads of some of the types of wheat are illustrated in Figure 92.

FIG. 92. — Types of Wheat.

a, emmer; *b*, blue stem; *c*, macaroni; *d*, fife; *e*, bearded common.

As a rule, the more humid the region, the softer the wheat will be. The vast prairies and rolling country of Canada and the Dakotas produce a hard spring wheat that ranks with the hard winter wheat of Ne-

braska and Kansas in the production of fine flour, although the soft winter wheat of the middle states westward from New York, Ohio, and 'southward makes excellent pastry flour.

Durum, the hardest variety of wheat, is used in making macaroni. This wheat has been almost entirely imported until the past few years, but the fact that it requires less rainfall than other varieties has led to its introduction in the western plains, especially in Kansas, Nebraska, and the Dakotas, with favorable results.

Some of the principal advantages in growing winter wheat are a better distribution of farm work; generally higher yields, largely due to the maturing of the crop before the extreme heat of midsummer, which often prevents full development; a conservation of soil fertility by the crop during the autumn and spring; and, in some localities and under certain conditions, an increase in pasturage.

Note. — Winter sown wheat may be pastured during the late fall and winter without material injury to the growth of the plant in the spring. In fact, it has been thought that judicious pasturing of wheat helps to thicken the stand by increasing the number of stems to the plant.

Emmer, sometimes miscalled Speltz, is grown to some extent in this country as a stock food. The hull of this wheat adheres to the kernel as it does in barley.

Wheat Sowing. — As wheat thrives best in somewhat solid soil, clays or clay loams, if well drained, will yield the most satisfactory results, but the different varieties of wheat demand varying conditions, spring wheat growing well on lighter soil than winter wheat.
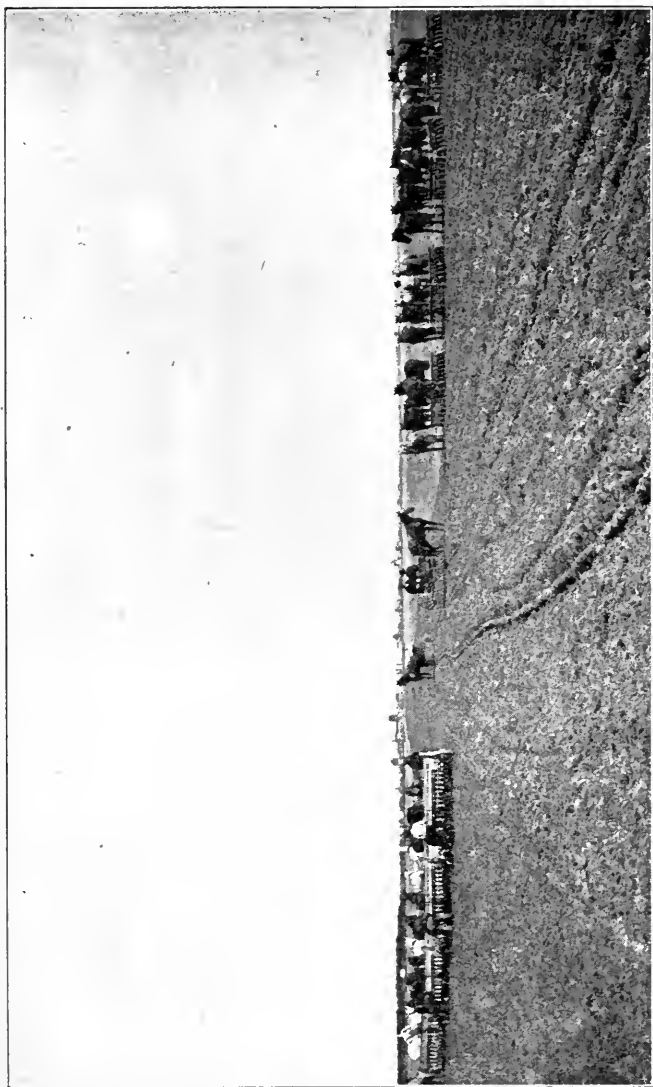
FIG. 93. — Disking and Seeding Wheat.

Experiments have shown that early plowing and early seeding of winter wheat, preferably the first week in September in the northern states and late in September or early in October in the states farther south, produce the best yield. The ground for spring wheat planting should be plowed the previous autumn and the seed sown in the spring as early as possible.

If the crop rotation brings wheat after clover or corn, little or no added nitrogen will be required, and if the preceding crop has been furnished lime, potash, and phosphorus, no additional fertilizer will be needed.

Preparation of Seed Bed. — The practice as to depth of plowing varies in different localities. As wheat has a shallow rootage, it has been thought necessary to plow but four to seven inches in depth. This allows the roots to spread out on the subsoil where they receive the maximum amount of moisture and at the same time a plentiful supply of air in the plowed surface.

Shallow plowing has resulted in early exhaustion of the topsoil and consequent lessened yields of wheat, so that, as usually practiced, deep plowing stirs up the soil to a depth of six to eight inches and has the following advantages:

(*a*) It allows the soil to absorb a large amount of the rainfall.

(*b*) It renders available for plant growth a larger amount of plant food.

(*c*) It buries many weeds that would otherwise spring up to choke the wheat.

Many who practice deep plowing use the subsurface packer (see page 95) to reëstablish capillarity between the surface and the subsoil.

As soon after plowing as practicable the surface should be harrowed and made as fine as possible. Then the grain is sown broadcast or it is drilled in. If it is sown broadcast, another harrowing should be given to cover the grain.

There are some advantages in the use of a drill. This machine plants the grain at a uniform depth and covers it at one operation. The plants germinate and grow to maturity more uniformly than with broadcast seeding. There is also a saving of one to two pecks of seed wheat to the acre.

For the sake of conserving soil moisture, some good farmers harrow the wheat after it has sprouted and has grown an inch or two in height. A few plants may be destroyed, but the gain to the crop far outweighs the slight loss.

Harvesting. — The proper time for harvesting wheat is indicated by the straw turning to a yellow color. It is not best to wait till the wheat is dead ripe, as many of the kernels fall out of the chaff and are lost in the operations of cutting, shocking, and stacking. When the kernel of wheat has passed the soft milk and dough stage, but is still soft enough to be indented by the thumb nail, the grain is in just the proper degree of ripeness to harvest.

The self-binder is used in most parts of the United States. This cuts and binds the wheat into bundles. They are then put into shocks properly capped until they may be built into stacks at the place where the threshing is to be done. It takes from one to two weeks for the grain in the stack to lose the extra amount of moisture that it contains, that is, it is said to go through the sweat process. Very often the stacking is omitted

and the bundles of grain are hauled directly to the machine for threshing. The sweating process must then take place in the bin. Frequent shovelings are often necessary to prevent the moist grain from getting very hot.

Note. — On the large farms in the western part of the United States, a machine called the header is used. This cuts off the heads of the grain, letting the straw remain standing. The heads are carried into the machine and are there directly threshed. This is a large machine, a harvester and thresher in one, and requires a great number of horses to pull it.

Weight and Yield of Wheat. — Sixty pounds is the standard weight for a bushel of wheat. If it is lighter than this standard, its quality is reduced. The harder and heavier wheat gives the best quality of flour and brings the highest price in the market.

The average yield of wheat in this country is 14 bushels to the acre. In the northern states 20 bushels is considered a good fair yield, but many farmers are able to secure from 30 to 40 bushels to the acre.

Corn. — The United States is the great corn-growing country of the world, four fifths of all her farmers being engaged in the industry with a yield that is greater than all the other countries put together and fifteen times that of Argentina, which ranks second. The annual crop is over 2,500,000,000 bushels, which would furnish each man, woman, and child in the country with 25 bushels. Its double use as food for man and beast keeps the demand commensurate with the supply or even beyond it.

Note. — If the corn crop of the United States for 1906 had been placed in wagons, 50 bushels to a load, and 20 feet of space

allowed for each wagon and team, the train of corn would have reached nine times around the earth at the equator. — *Cyclopedia of American Agriculture.*

All the states in the temperate belt raise more or less corn, but the seven where " corn is king " are Illinois, Iowa, Missouri, Indiana, Nebraska, Ohio, and Kansas. The corn plant is a native of North America, probably originating in Mexico, although it thrives well in the regions farther north. The early settlers in this country were taught its use and culture by the Indians, who had cultivated each season their fields of maize from time out of mind. It formed the staple food of the first settlers in each successive region to the west. While not so much used for human food now, its increased use as fodder, both in its green and its matured state, has induced farmers in certain states especially adapted to its growth to increase the acreage from year to year, until now one third of the tilled land of this country is planted to corn.

Selecting Seed Corn. — Germination tests for seed corn have been described on page 151. Professor Holden, Iowa, says : " One of the best plans is to select fifty or one hundred of the very best ears in the seed corn, while making the test of germination. These ears should then be butted and tipped and each ear shelled by itself and carefully studied. The kernels should have a bright, cheerful appearance, be full and plump at the tips and have a large clear germ, otherwise they should be discarded."

All the seed corn for the next crop should be selected from the patch which was planted from the very best ears. It is a very common practice to select the occasional good ears found throughout the husking season.

There are three important reasons why this should not
be done. In the first place, we are more likely to neg-
lect the work until too late, when we find ourselves
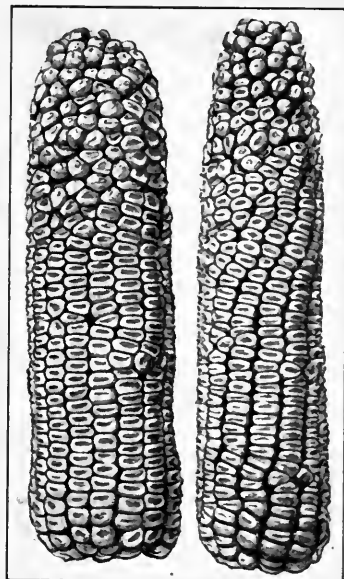

FIG. 94.   FIG. 95.

Fig. 94, two good ears of seed corn. Note the straight rows of kernels, and the well-filled butts
and tips. Fig. 95, two poor ears of seed corn. Note the crooked rows and irregular sized
and shaped kernels. No corn planter can plant uniformly such seed corn. (Extension
Division, Minnesota Agric. Dept.)

without good seed for the next year. Again, we often
begin harvesting from the poorest parts of our fields
first for early feeding, as this corn is more likely to be
soft and will not crib well. The chief reason is that
the occasional good ears which are harvested through-
out the husking season have necessarily been fertilized
to a greater or less extent by pollen from the scrub
stalks and those which are perhaps barren.

Note. — In the northern states early selection of seed corn is necessary so that it may be thoroughly dried before freezing weather comes. Freezing before the corn is thoroughly dried is almost certain to injure the germ.

It is a good practice and one followed by many corn growers to go through this seed patch of three or four acres planted from the fifty or sixty best ears of corn, after it has been laid by and before the tassels appear, and to cut out all the weak and sickly stalks and those that are too tall and late or too short and early and in this way to prevent them from producing pollen to fertilize the kernels of other ears.
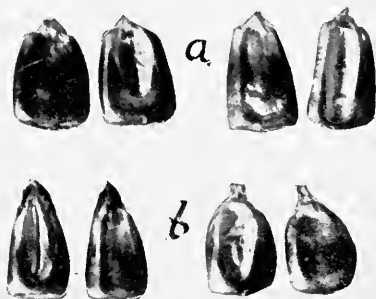
Fig. 96.

a, good types of kernels of corn. Note the broad tips. Such kernels are richer in food nutrients, have larger, stronger germs, and yield a larger proportion of corn to cob, than do kernels with small pointed tips, like those shown in *b*.

The best soil for corn in one region is not necessarily the best in another. In the central prairie states the ideal corn soils are a silt loam or a black clay loam, but these are not at all the most desirable corn soils for the northeastern and eastern tide-water states. Here the gravelly and stony loams are better, because the greater elevation and consequent shorter season make it necessary to have at once a well-drained, well-warmed, and moisture-retaining soil to satisfy the demands of a heavy, rank-growing crop. On the other hand, in the southern seaboard states, owing to different climatic conditions and altitude, the heavy loams and clays are best adapted to corn.

Whatever the nature of the soil in which corn is to be planted, it must be made light and mellow if the

FIG. 97. — Selection of Seed Corn from Standing Corn.

When corn is selected in this way, one can consider the stock from which the ears are taken as well as the ears themselves. (Extension Division, Minn. Agric. Dept.)
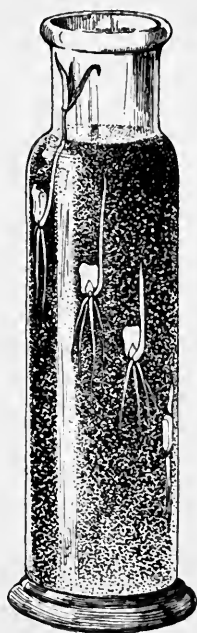
FIG. 98. — To show the Best Depth at which to plant Corn.

plant is to thrive. Fall plowing followed by spring replowing, if the soil is heavy, and harrowing will place the soil in the proper condition.

The depth at which corn should be planted depends upon the nature of the soil, varying from one inch in humid regions to two or three inches in the drier regions or in sandy soil. The Indian method of planting

four grains in a hill four feet each way has not been materially changed by modern methods. Three or
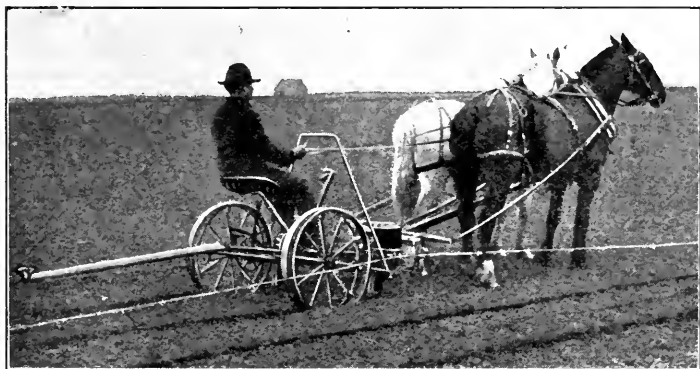
FIG. 99. — Check Row Corn Planter.

four kernels in hills $3\frac{2}{3}$ feet apart is now the general rule. This permits easy cultivation of the field both ways. Another method is to plant in drills. Good
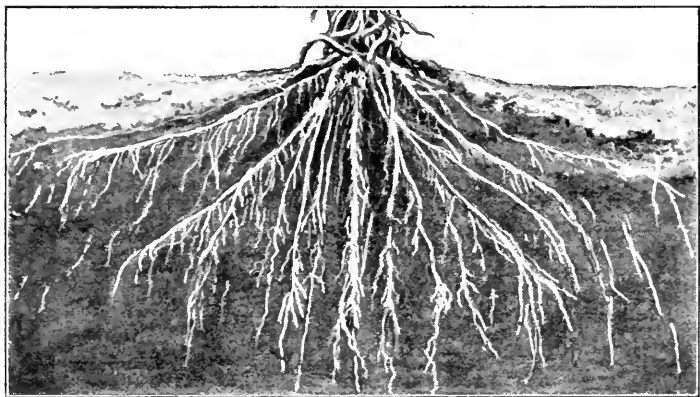
FIG. 100. — Root Distribution at Silking Time. (Yearbook U. S. Department of Agriculture.)

results as to yield may be obtained by this method
if the land is reasonably free of weeds. Much of the
success in raising corn, so far as man can affect it,
depends upon keeping the weeds down and the surface
of the ground well tilled. Early cultivations may be

FIG. 101. — Two-row Cultivator.

deep, but the later ones should be quite shallow, so as
not to disturb the roots.

Suggestive Experiment. — To determine the best depth at which
to plant corn, fill a glass jar with garden soil to a height of 5 or 6
inches from the top, put in a kernel of corn flat against the side of the jar;
put in another inch of soil, then another kernel of corn as before, and con-
tinue this until the jar is full, arranging the kernels spirally as shown in
Figure 98. Moisten the soil, cover the bottle up to the neck with black
paper or cloth and set it in a warm place. By taking off the covering
and examining the seeds daily you can determine the best depth at which
to plant corn.

The best time to kill weeds is before they have made much growth. Frequent and shallow early cultivation effectively destroys the weeds and forms a dust mulch to prevent surface evaporation. Aside from these two things, the farmer can do nothing to better his crop after the selection of the seed is made and the planting done. Hot days during the growing period, bright sunshine and plenty of it, and abundant rainfall constitute good corn weather, but these are not under man's control.

The corn is now usually harvested by cutting to the ground while still comparatively green, and putting it
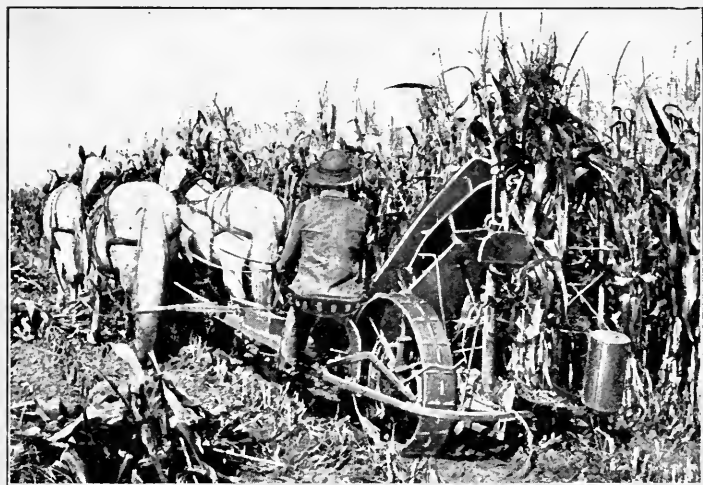
FIG. 102. — Corn Harvester.

up in shocks of good size, securely tied at the top. When the stalks, or *stover*, are well cured, the corn is usually ready to husk. It should be stored in cribs

which allow the freest possible circulation of air. Corn is also often fed from the bundle to fattening steers.

Good corn land should yield from 80 to 90 bushels of shelled corn an acre. The fact that the average yield in the United States is only 25 to 35 bushels an acre shows poor seed, impoverished land, poor cultivation, or a combination of these poor conditions.

Corn Products. — Corn, while used principally as food for animals and man, furnishes the basis of many other products. Among these are alcohol, whisky, and malt liquors. Glucose and corn starch, used respectively in the making of confectionery and in cooking, are two other well-known products. All parts of the maize plant have other uses than as a food, for the stalks and husks are made into a coarse paper, the pith forms a packing for stopping leaks and is therefore carried on war vessels, while the cobs are made into pipes. Gluten meal, a common stock food, is also made from corn.

Fig. 103. — Section of a Silo.

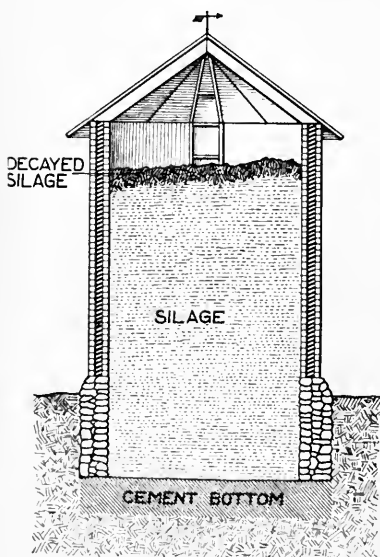**Silos and Silage**. — A *silo* is an air-tight structure, used for the preservation of green, coarse fodders in a juicy condition. *Silage*, or *ensilage*, is the food taken out of a silo.

Indian corn is preëminently the American crop suited to be preserved in silos, but clover, alfalfa, cowpeas, soy beans, Canadian field peas, sorghum, and sugar beet pulp in this country, and meadow grass and aftermath in England and the Scandinavian countries, are also preserved in this manner. Agricultural literature mentions the siloing of a large number of plants, like vetches, small grains (cut green), cabbage leaves, sugar beets, potatoes, potato leaves, turnips, brewers' grains, apple pomace, and refuse from corn and pea canning factories.

Advantages of the Silo. — 1. The silo preserves a larger quantity of the nutritive materials of the original fodder for the feeding of farm animals than is possible by any other known system of preservation.

Grasses and other green crops lose some of their food material when made into hay. Indian corn loses at least 10 per cent of its food value when cured in shocks even under the best conditions, while in ordinary farm practice the loss approaches 25 per cent. Exposure to rain and storm, rubbing off dry leaves and thin stalks, and other factors tend to diminish the nutritive value of the fodder, so that very often only one half of the food materials originally present in the fodder is left by the time it is fed out. In addition, the remaining portion of the fodder is less digestible and less nutritious because the fermentation occurring during the curing process destroys the soluble sugar and starch so necessary in digestion.

On the other hand, the maximum loss in the modern, deep, well-built silos is 10 per cent. Professor King believes that the necessary loss of dry matter in the silo need not exceed 5 per cent.

2. *Ensilage* is juicy, and juiciness is characteristic of

food in the natural form. To appreciate this we need only think of the difference between a ripe, juicy peach and the dried fruit. In the drying or curing of hay or other fodder water is the main element removed, but with it go certain flavoring matters that make the food pleasant to the taste.

3. *The silo furnishes a feed of uniform quality readily accessible and available the whole year.*

This is especially valuable in the case of milch cows and sheep, which are particularly sensitive to change in their feed.

4. *The silo furnishes the most economical means of storage of fodder.*

A ton of hay stored in mow will occupy a space of about 400 cubic feet, a ton of silage about 50 cubic feet. Counting the amount of dry matter in the ton in the mow and in the form of silage, to store the same amount of food requires about three times as much room in the form of hay as in silage form.

In the case of field-cured fodder corn the silo is still more economical. According to the figures of experts an acre of fodder corn, field-cured, stored in the most compact form possible, will occupy a space ten times as great as in the form of silage.

5. *The silo preserves the fodder from rain.*

This prevents losses due to leaching out of nutrients and molding after wetting.

6. *The silo carries the stock through the late summer droughts if filled with clover or other green crops earlier in the season.*

7. *Silage makes it possible to keep two cows where one was kept before.* The same area of land will support more stock than when pasturing is practiced.

Silo Structures. — *The silo must be air-tight.* Bacteria enter the silo with the fodder and grow and multiply rapidly, as shown by the heating of the mass and the formation of acid in it; in other words, fermentation begins. If the silage is well packed so as to leave no unfilled spaces and the silo walls are air-tight, then only acid fermentation, which is desirable, takes place. If more air gains entrance, bacteria causing decay will

FIG. 104. — Students constructing a Concrete Silo. (U. S. Dept. of Agriculture.)

continue the work of the acid-forming bacteria, and rotten silage will result.

The silo must be deep. Depth is necessary in order to secure pressure on the fodder and thus leave as little air as possible in the mass. From 30 to 40 feet is now recognized as standard depth.

The silo must have smooth, vertical walls which will offer no resistance to the uniform settling of the fodder. Otherwise air spaces may be formed, and thus the fodder be spoiled.

The walls of the silo must be very strong so as not to give way as the mass settles. The outward pressure of cut fodder corn is great and the walls of rectangular silos especially are apt to spring. In the round wooden silos every board acts as a hoop, and as boards stretch but little lengthwise, there is little spreading in these silos. Stave silos secured by iron hoops have proved satisfactory in resisting pressure from settling and are used very extensively. Very satisfactory silos are also built of brick, of hollow tile, of cement blocks. Probably the most satisfactory silo is the cylindrical reënforced cement silo. It has all the advantages of the best wooden silos and in addition it is practically everlasting.

The size of the silo must, of course, be determined by the size of the herd to be fed from it. It has been determined by experiment that about 40 pounds daily is a good average food ration for cattle a head. If the season for feeding is 180 days, this will mean 7200 pounds for each cow. As silage loses about 10 per cent in weight by fermentation, there must be put into the silo about 8000 pounds, or 4 tons, for each animal. One ton of silage occupies about 50 cubic feet, therefore the fodder for one animal will require a space of 200 cubic feet, approximately.

The following table shows the capacity in tons of circular silos from 20 feet to 36 feet in depth, and 10 feet to 18 feet in diameter, also the number of acres of corn, averaging 10 tons to the acre, necessary to fill

each, and the number of cows the contents of each will keep for 180 days with 40 pounds of feed a day.

Dimensions	Capacity Tons	Acres to fill, 10 Tons to Acre	Cows it will keep 6 Months, 40 lb. Feed per Day
10 × 20	28	2.8	8
12 × 20	40	4.0	11
12 × 24	49	4.9	13
12 × 28	60	6.0	15
14 × 22	61	6.1	17
14 × 24	67	6.7	19
14 × 28	83	8.3	22
14 × 30	93	9.3	23
16 × 24	87	8.7	24
16 × 26	97	9.7	26
16 × 30	119	11.9	29
18 × 30	151	15.0	37
18 × 36	180	18.0	45

Filling the Silo. — Corn has the largest amount of food material in it when it is well matured, the sugar having then largely changed to starch. To cut corn for silage when the kernels are well dented has been found to produce the best results. Then the kernels are just beginning to glaze and are firm and in their best condition. If cut at an earlier stage, the sugar, which is then present in large quantities, is the first to be lost in the silage, and much food material is thus wasted.

Clover for silage is cut when just past full bloom, the same time it is right for making into hay.

The crop for silage must be cut in an ensilage cutter into portions of a size convenient for feeding, usually

in half-inch lengths. Corn ensilage must usually be trampled upon and evened as the layers are put in, in order to distribute the parts evenly.

Note. — A flexible pipe called a distributor is attached to the end of the blower pipe at the top of the silo. This carries the silage down into the silo and as the man in the silo shifts it about the silage is distributed evenly. As the silo is filled, lengths of the distributor pipe are removed.

FIG. 105. — Filling a Silo.

Special care must be taken to trample well near the walls as their surface offers some resistance to the settling mass. In the more modern deep silos, less trampling is necessary, but the surface must be kept even.

If delay occurs during the filling of the silo, care must be taken to leave an opening at the level of the silage for proper ventilation, otherwise the carbon dioxide which forms above the mass will suffocate one descending into it.

It is now quite a common practice to add water to corn silage if it goes into the silo in a dry state because of drought or very hot weather. About ten pounds of water to the square foot when filled, and a like quantity ten days afterwards, has been tried at the Wisconsin Experiment Station with satisfactory results.

Oats. — In latitudes too far north to grow corn successfully, oats thrive, while they will also grow well in all the Gulf states if sown in the fall. Somewhat heavy loams give the best yield, although most varieties of soils, except the lightest, will produce a good crop unless there may be too much humus present, in which case the plant runs to straw and yields little grain. As a rule, oats do not require direct fertilizing unless there is a lack of organic matter in the soil. Manure must be used sparingly, if at all, or the oats straw will be heavy and lodge easily in the summer rains.

Fall plowing, followed by spring harrowing and early sowing, either broadcast or in drills, is generally considered best for oats, although in America good crops are obtained without plowing the ground if the oats are put in a field previously planted to corn. Eight to ten pecks will seed an acre of ground.

It is a common thing in Canada to see barley and oats or these two and field peas sown together, the grain yield being better than would be produced from each separately. In the south hairy vetch is often mixed with oats when grown for fodder. If sown in the fall, these two followed by a crop of peas make the land in fine condition for cotton the next spring.

Note. — Since most varieties of oats stool freely and a single kernel produces a number of stalks of grain, some farmers seed sparingly, claiming that just as good results are obtained as if a larger amount of

seed were used.   Others claim that grain should be sown thick enough to prevent stooling, so that the nourishment from each kernel may be sent into a single culm, thus making a more vigorous plant.
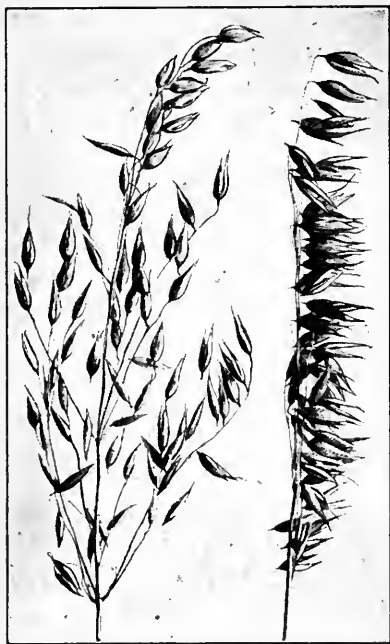
Varieties and Yields. — There are two common species of oats, one with branches on all sides of the stem, open and spreading, our common oats, and the other with branches on one side only, called side oats, or horse mane oats. Of the first kind, the white varieties are the most cultivated.

FIG. 106. — Two Types of Oat Panicles.

a, the open, or spreading; *b*, the side, or horse mane.

Thirty-two pounds of oats is considered a bushel, approximately one fourth of which is hulls and three fourths kernel. In the cooler portions of the temperate zones oats often weigh as high as 45 to 50 pounds to the measured bushel. For exhibition purposes oats are frequently clipped or rubbed, depriving them of the end of the hull surrounding the kernels. This removes the lighter part of the oats and increases the weight per bushel. It is customary for judges to throw out from competition at once samples of oats that have been clipped or rubbed too much.

The average yield for the United States is between 30 and 35 bushels to the acre, but under ordinary conditions a yield of anything less than 40 bushels to the acre should be considered poor.

The United States exported seven times as many bushels of oats in 1901 as 1905, yet the yield in the latter year was 200,000,000 bushels greater than in the former. These figures show that home consumption of this grain is increasing, either as food for horses or for man in the form of oatmeal, rolled oats, and other oat breakfast foods.

Barley. — This grain is of much less general importance than the three preceding. It is grown almost entirely to make malt for the brewing of beer, although it has an increasing use as food for stock. In the past ten years there has been in the United States an increase of 1,000,000 acres devoted to barley raising, with an increased yield of 30,000,000 bushels.

The classification of barleys is based upon the number of rows on the head, — two, four, or six. Barley grown for the brewers in Europe is usually of the two-rowed variety, a slow ripener. In the United States the six-row variety is generally grown both for brewing and for feeding purposes.

Hull-less barley is grown for feeding purposes, but does not usually yield as much as the other varieties.

Barley has the shortest straw of the small grains. The heads are usually armed with long, strong, spreading beards that grow from the tips of the glumes. These beards make the handling of the straw uncomfortable, and when eaten by cattle or horses they stick into the gums, causing considerable distress.

The hull of the barley grows tight to the kernel,

and the grain instead of being roundish has a distinctly ribbed or angular appearance.

For best results barley should have rich, well-drained soil. The soil should be light to medium, and if the grain is grown for malt, not too rich in nitrogen. In

FIG. 107. — Types of Barley.

a, hexagon, 6-row; b, manshury, 6-row; c, duckbill, 2-row; d, beardless, 2-row; e, long, 2-row; f, Mandschvri, 6-row; g, beardless, 6-row. (Minnesota Experiment Station.)

England, where the soil and climate are particularly adapted to this grain, barley is commonly sown in land previously planted to turnips. The latter crop is usually consumed on the land by sheep, and their manure enriches the soil for the succeeding crop. Barley so grown usually produces high yields per acre of grain of best quality.

From seven to nine pecks of barley will seed an acre. Seeding may be a little later than for oats. Forty-

eight pounds of barley is the standard for a measured bushel. For hull-less barley it is sixty pounds for a bushel.

The price of malting barley depends largely on its bright, clear appearance, which indicates high germinating power. Barley discolors very easily, and great care should be taken to keep it from drenching rains after it has been cut in the fields.

Rye. — The relative unimportance of rye in this country is revealed by the statistics of the Department of Agriculture, which show that the United States raises only about one fifth as much rye as barley. Yet this small amount is seven eighths of the entire crop of North America. Germany produces annually twelve times as much as North America, France twice as much, while Russia's crop is over twenty times as great. The large production of this grain in these European countries is due to its use there in making bread, the wheat crop being uncertain, the consequent price placing it beyond the reach of the peasantry.

Rye is adapted to the cooler regions of the United States and is often sown on land too poor for other grains. It is usually sown in the fall, for it stands winter freezing without damage to the yield. It may be used for pasturage, and it may be turned under as a green manure.

Rye has the same classification as wheat, namely, spring and winter. The latter variety is the more productive, and consequently cultivated more extensively. The grain may be distinguished from wheat by its longer, slenderer, and more wrinkled appearance. An average yield of rye is 20 bushels an acre, and the standard weight is 56 pounds a bushel. In some places

in Europe rye is sown in midsummer, mowed for green fodder in autumn, and left to produce a grain crop the following spring. It may also be pastured judiciously in spring without harm; when handled in this way it generally produces a good crop of small but very mealy grain.

Rye straw, being tougher and longer than that of the other grains, is much used for plaiting, for the manufacture of horse collars, for packing material, and commands a higher price than that of the other small grains.

Buckwheat. — This grain is a native of the Volga basin, the shores of the Caspian Sea and central Asia. It is said to have been brought to Spain by the Moors and thence spread over western Europe, but another account ascribes its introduction there to the crusaders. The seed is gray or black and triangular, resembling the beechnut, from which the Germans named it beech-wheat, which the English corrupted to buck-wheat.

Buckwheat is usually classed as a grain, but it must not be thought of as belonging to the grass family, as do the other grains. It belongs to the smartweed family.

Buckwheat is sown broadcast or in drills. If the former, about a bushel of seed is required; if the latter, only three quarters of a bushel. It will grow well on light, poor soils. When green-manured, it furnishes a large quantity of humus to enrich the soil.

Bees utilize the nectar in its flowers for honey, and in some parts of the United States it is sown on this account. As a supplementary food for man in the form of griddle cakes, it is a very palatable and nutritious article of diet.

Rice. — This grain, one of the most useful and extensively cultivated of all grains, supplies the staple

Fig. 108. — A Field of Rice.

food of nearly one third of the human race. Originally a native of the East Indies, it is now cultivated in all quarters of the globe where conditions of warmth and moisture are suitable; in subtropical countries where there is much moisture in the soil, the rice plant thrives well. The head of the rice plant is bearded like barley, but is borne in loose heads, or panicles, at the top of

the stem somewhat as in oats, and when unhusked resembles barley.

In China rice is sown in seed beds and afterwards transplanted. The rice grounds are carefully kept free from weeds, although often so wet that a man cannot walk in them without sinking to the knees. In many parts of China two crops a year are obtained.

In South Carolina, where the best rice known in the market is grown, although not in large quantities, the grain is sown in rows in the bottom of trenches about 18 inches apart, the trenches are filled with water to the depth of several inches till the seeds germinate, the water is then drawn off and later the field is flooded again for two weeks to kill the weeds. When the grain is near maturity, the field is flooded again.

It might be supposed that marshy lands were adapted to the culture of the grain, but it has been found that land where there is always the same abundance of water is not so suitable as those in which the supply of moisture can be regulated according to the season and the growth of the plant. Louisiana, Arkansas, and Texas have good soils for rice culture. There the grain is planted with drills just as wheat is in northern latitudes, and water is turned on when the plants are from five to six inches high.

Rice is harvested, threshed, winnowed, and placed in sacks much as wheat is, the land by the time the grain is fully matured being compact enough to bear the weight of machinery. Rice yields much more grain than wheat to the acre and brings about the same price, but as the cost of production is greater it may not be a more profitable crop.

Fall-grown cowpeas, velvet beans, or hairy vetch green-manured in the spring will render a field in good condition for planting rice in early June.

Uses of Rice. — Rice is a fat-producing and heat-giving rather than a flesh-forming food. Owing to the small quantity of gluten it contains, it is unfit for being baked into bread. The Japanese make a beer from it which is in general use among them, but is always heated before being drunk. The Chinese make several kinds of rice wine, some of which they esteem very highly because of their great intoxicating qualities.

A starch made from rice is in common use in England in laundries and muslin manufactories. Rice straw is much used for plaiting. The refuse from cleaning rice for market, known as rice meal and rice dust, is valuable as a stock food. Experiments are being made in Texas with satisfactory results in feeding poor rice crops to stock. There is a considerable loss each year from the fact that a certain portion of the crop is unmarketable owing to damage in harvesting or storing. It is thought that if rice meal is valuable as a stock food, the whole grain may be even more so. This use of the damaged crop or of the surplus in some years may prevent much waste.

Sugar Plants

Sugar Cane. — The three sugar plants are *sugar cane*, *sorghum*, and *sugar beets*. The united farm value of sugar beets and sugar cane in the United States and her possessions in 1912 was more than $60,000,000. The sugar cane is grown in all the South Atlantic and Gulf states for sirup making, and for sugar making in Florida, Louisiana, and Texas. It is a well-known fact

that sugar cane when grown on poor, sandy soils produces a purer sap and one which makes a lighter colored sirup than when grown on dark or very fertile soils, but the former soils, being very deficient in plant food, must be well fertilized in order to produce a crop of sufficient magnitude to make the growth of sugar cane profitable. A crop of 15 to 25 tons an acre is quite common under such conditions. Each ton will make from 18 to 24 gallons of sirup where up-to-date methods of extraction and evaporation of the sap are used.

The sugar cane is one of the grasses. It has fibrous roots and a stalk made up of joints filled with pith. It varies in length from 4 feet to 15 feet, depending on the variety. Although the sugar cane bears some fertile seeds in its tassel, it is not through them that the sugar cane is propagated, except for experimental purposes. At the node under the base of each leaf there is a bud, or eye, which is used for growing the next crop of cane.

For planting, the ground is prepared by deep plowing, then rows 5 to 7 feet wide are made by throwing up the soil into high ridges. A furrow is plowed through the length of the ridge, in the bottom of which the canes are laid in continuous lines and covered with about four inches of soil. Here they lie protected against frosts till spring, when the earth is thrown from each side of the cane by plows, and all but a slight covering of soil is removed from the cane. Being thus laid on a well-drained ridge, the eyes commence their growth earlier than they otherwise would.

After the cane has come up, a fertilizer is applied and the canes are recovered with earth. A disk cultivator is used as often as is necessary between the rows,

and when the cane has grown so that this is prevented, the hoe is used to keep the crop free from weeds.

Sorghum. — Sorghum as a fodder has been mentioned on page 199. The plant is also used as a grain in semi-arid regions of the west where the corn crop is uncertain.

The sorghums are giant grasses with solid, pithy stems. The leaves are long and broad. The planting and tillage are very much the same as for corn.

Although originally a semitropical plant, sorghum has wider adaptation than corn, and this, with its ability to withstand a more protracted drought, has made it a common crop throughout the country, its production having increased enormously in recent years.

Broom corn, Kaffir corn, Jerusalem corn, durra, and

FIG. 109. — Kaffir Corn.

milo maize are varieties of the sorghum plant without sugar enough for sirup making.

Broom corn is used in the manufacture of brooms. There are two types of this plant, the standard and

the dwarf types, the standard variety growing to a height of from 10 to 15 feet, while the dwarf variety grows from 4 to 6 feet in height. The dwarf broom corn is used in making whisk brushes, and the standard variety in making large brooms.

Kaffir corn, Jerusalem corn, durra, and milo maize are grown for their seeds, the most important of which is the Kaffir corn. They are very similar in many respects and are especially adapted for growing in regions lacking a plentiful supply of moisture. They are particularly valuable on the semiarid plains of the southwest.

Sugar Beets. — Beets grown for making into sugar must receive somewhat different treatment from that
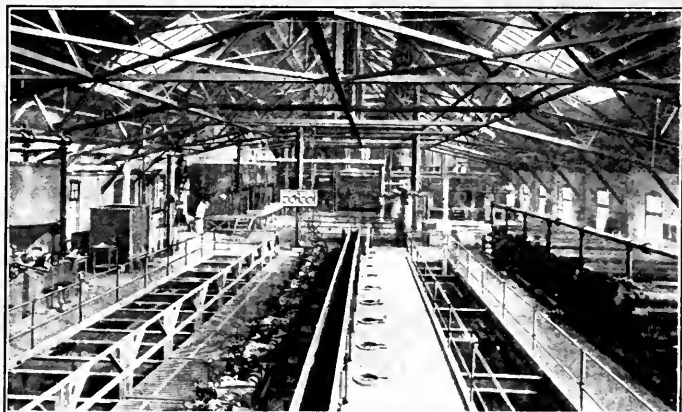
Fig. 110. — Beet Sugar Factory, Nebraska.

given when they are grown as a vegetable. Numerous experiments conducted under the direction of the United States Department of Agriculture have proved that the best soil for the sugar beet in all the arid regions is the

sandy loam. In Wisconsin, Michigan, and central New York heavier loams or clay loams, if well supplied with moisture and not too stiff, are best adapted to this crop. Too much humus or nitrogen will make the plant run to leaves and reduce the sugar content. The profits of the crop depend upon the yield and the percentage of sugar from the beets, for most factories pay for their beets on the basis of the sugar content. As this percentage depends largely upon the grade of seed sown, it follows that careful selection of seed is the first factor in raising sugar beets profitably. Efforts are now being made in various states to produce seed of superior quality by scientific methods. Where this is done and the farmer is careful to get his supply from this reliable source, the percentage of sugar may be expected to equal that of Germany, where the industry has reached its highest development.

The soil requires deep fall plowing after manure has been applied, followed by spring plowing and thorough harrowing. The soil must be mellow or the roots may protrude above the ground, in which case that portion exposed to the air will be entirely wasted. The drills for the sugar beet are about one and one half to two feet apart. It is not desirable that the roots shall be very large, and in thinning them after the plants have attained a little growth above the ground, a space of no more than six inches should be left between the plants. In some localities young plants are transplanted like cabbages. This, with the careful cultivation necessary, makes the labor cost of production high.

Sugar beets must be harvested before the frosts come. The roots may be loosened by machinery; they are then pulled and the tops cut off. If they cannot be

hauled at once to the factory, they should be stored in
earth-covered piles in the open air.

Oil Plants

Of the oleaginous, or oil-producing, plants, cotton
probably ranks first. Formerly the seeds of this plant
when separated from the fiber were treated as waste
matter, to be disposed of in the easiest and most eco-
nomical way possible. Experiments finally demon-
strated their great worth, not alone for the oil in them,
but also for their fertilizing and stock-feeding value.

The United States exported over 50,000,000 gallons
of cottonseed oil in 1912, with a value of $15,000,000.

Flax seed yields an oil, called linseed oil, which is
much used in the manufacture of varnishes, paints, and
printer's ink.

Castor oil is made from the castor bean, and the
pomace, which remains from the extraction, though
poisonous, is an excellent fertilizer, containing potash,
phosphoric acid, and nitrogen. The most important use
of castor oil in this country is for dyeing cotton goods.
Its second important use is as a medicine. Its use as
a lubricant is quite common in all countries.

The olive is cultivated in southwestern United States
and California, not only for the fruit which is put into
a brine when green, but also for the oil which is extracted
from the ripe fruit and used for salads and cooking and
also as medicine.

Fiber Plants

Cotton easily ranks first among the fiber-producing
plants in production, value, and importance. The
so-called cotton belt includes almost the whole of the

United States south of latitude 35 degrees. In this belt is produced over two thirds of the world's crop
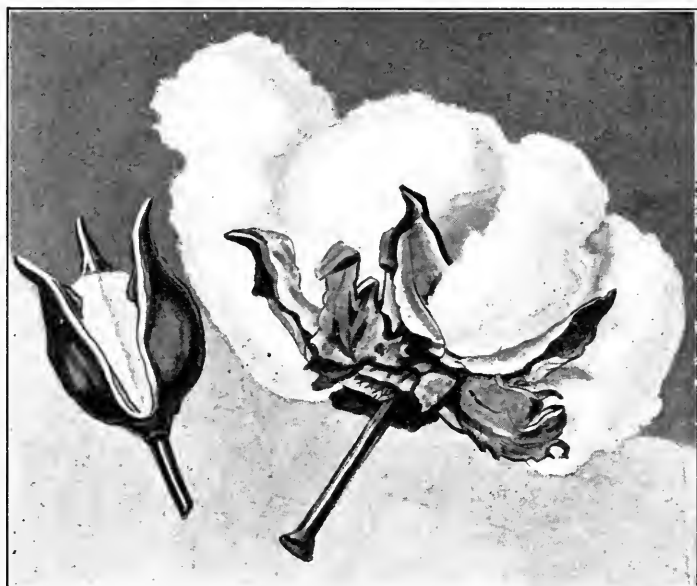
FIG. 111. — Cotton Bolls.

of this staple. This plant will grow on good soil and it will grow on poor soil. It will yield rich returns when the soil is well prepared, well cultivated, and well drained, and when the opposite conditions prevail, the crop is not by any means a failure.

As the great enemy of the cotton plant, the boll weevil, is constantly extending the range of its ravages, the United States Department of Agriculture urges upon cotton growers methods which will secure an early maturing of the crop in order that the injurious results of the insect may be minimized. Early plowing, the

first one being in the preceding autumn, resulting in a mellow soil from 6 to 10 inches deep, followed by throwing up ridges, which are subsequently harrowed, with well-defined water furrows between, is the first step. The application of readily soluble fertilizers from one to three weeks before planting is advised, but an excess of nitrogen should be avoided.

A variety of cotton seed should be selected the habit of which is to bloom early, mature quickly, and open its bolls rapidly. Planting should be as early as past experience has shown to be reasonably safe. "Plant when the soil has been properly prepared and is in workable condition, and when the proper date has arrived," regardless of the temperature of the air and the direction of the wind. The plants should be set about 2 feet apart in rows which are 3 feet apart. Many planters reserve a part of the fertilizer and apply it directly in the furrows with the seed, but 25 to 40 pounds of the readily soluble nitrate of soda to the acre may be used instead.

Cultivating begins as soon as the plants are in sight, or even before if there is a heavy rainfall. Hand cultivation begins with the appearance of the third leaf, the object being to thin out the plants to the required distance apart and destroy any weeds which may have started. After this, cultivation once a week is practiced in order to maintain a good dirt mulch. Little if any cultivation should be given after the plants begin to bloom freely. The general rule is that early, frequent, and shallow cultivation tends to produce an early crop; deeper and later continued cultivation tends to delay the crop, but may increase the final yield in sections not infested by the boll weevil. It is recom-

mended that the entire field of plants shall be uprooted and burned in the fall after the crop has been picked.

Flax. — It has been said that no other plant not yielding food is so valuable to man as flax. It is highly
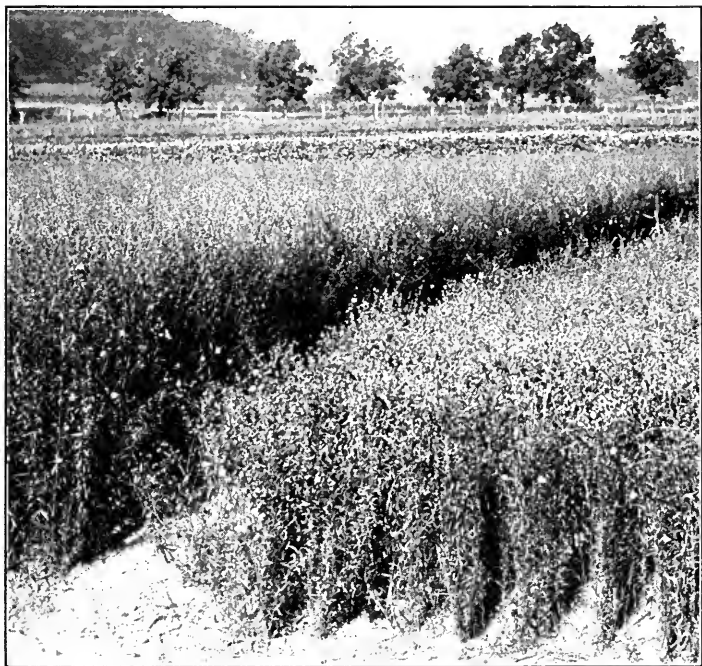
Fig. 112. — Flax, grown for Seed (left-hand plot) and for Fiber (right-hand plot).

valuable for the fibers of its inner bark, from which linen cloth of varying degrees of fineness is made, and for its seeds, which yield linseed oil, already spoken of under Oil. Oil cake is extensively used as feed for cattle, and linseed meal is used as a poultice. Flax fiber is one of the materials out of which paper is made.

Flax is grown in this country less for its fiber than for its seed. It will grow almost anywhere in the United States, but it needs a strong, rich soil and careful handling at every stage of its production and manufacture, its culture demanding a greater amount of labor than almost any other crop. Much depends upon the thickness of the sowing of flax. When sown thick and pulled before the seed is ripe, it yields a fine fiber, but if a coarser fiber is desired, the plants must be given more room. If grown for a coarse fiber and for seed, the plants must reach maturity before being harvested. It is then sown at the rate of from two to three pecks an acre. Flax plants are usually pulled, but in the western part of the United States and Canada, where the flax is grown for the seed only, it is cut with a reaper or with a binder.

It has been thought that flax drains the land of fertility, but experiments have shown that it does not equal corn or oats in this respect. It does deplete the soil of nitrogen, hence it should be preceded by clover or some other legume in the rotation. Almost the entire flax crop of this country is grown west of the Mississippi River. The largest yields are obtained from virgin prairie land. On account of a fungus disease, flax wilt, the yield, when grown on a field two years in succession, is materially lessened, or it may be a total failure. (See page 283.)

Hemp. — This plant, which produces a coarse fiber used in the manufacture of sailcloth, ropes, and the like, is an annual, native of warmer parts of Asia, but has been naturalized in many parts of Europe and America. It adapts itself to wide diversities of climate. It is easily injured by frost, but its rapid growth enables it

usually to reach maturity during the hot summer season of cold countries. It thrives best on moist alluvial soil. If conditions are favorable to rapid growth at first, the fiber is of greater length. Like flax, hemp is pulled soon after flowering, if cultivated for a fine fiber, but if a coarser fiber and seed are the object, the plants should mature. Caged birds are very fond of hemp seed.

FIG. 113. — Hemp.

STIMULANTS

Mints. — Of the plants which furnish stimulants, either medicinal or aromatic, the mints are the only ones cultivated to any extent on farms in this country. The plants of this family are fragrant perennials, the foliage containing an essential oil, which is extracted for various uses. The three best known species are the spearmint, used for culinary purposes, peppermint, used in making candy, and bergamot-mint, in perfumes. All mints have medicinal properties.

Any soil that is good for potatoes will serve for mints. This crop exhausts the soil upon which it is
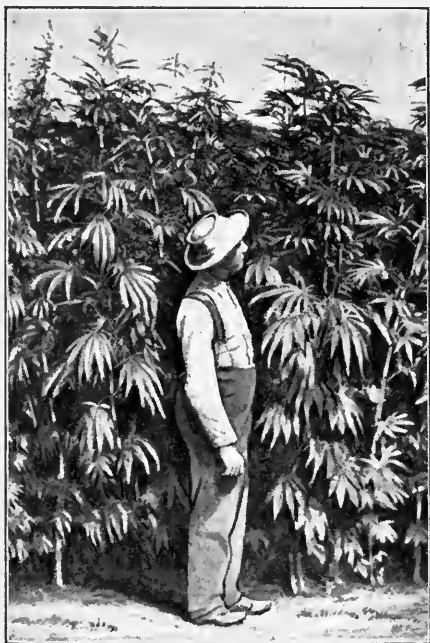
grown to such an extent that it should not be allowed to occupy the land continuously, except upon reclaimed swamp lands, where it may be grown years in succession. It is propagated by rootstocks (see page 154) set a few inches apart in shallow trenches 30 inches apart. It must be kept perfectly free from weeds, first by horse cultivation, then by hand. In midsummer the tops are cut and cured like hay, then stored under cover for distilling. In this country mints are raised most extensively in southwestern Michigan and northwestern Indiana.

Grasses

Grass Crop. — All the grasses and clovers that are used for pasturage and hay are known by the general term *grass crop*. In spite of the fact that the corn and wheat crops show a greater cash value, the grass crop is really the most valuable and the most important crop grown. The estimated cash value of the hay crop does not include the worth of the pasturage, of which there is an immense area in the United States. The production cost of the corn crop is much greater than that of hay, so that the net profits from the two crops are approximately equal. Again, the full value of hay to the farmer does not appear in the statistical figures of the value of the crop. The grasses, while being grown for hay, store the ground with humus by the decay of their roots and stubble, and forage plants rich in nitrogen, like the clovers, leave nitrogen, the most costly fertilizer, in the soil for the succeeding crop in the rotation. The indirect value of the grass crop to the farmer fully equals the direct cash value of the hay.

Professor Thomas Shaw says: " In the absence of grass, the humus supply in the land cannot be so well

maintained in any other way, which means that without it land cannot be kept for a considerable term of years in a proper mechanical condition. Without the grass crop weeds cannot be so readily kept at bay. In its absence some soils blow and others are carried away by the action of water, which may fall in the form of rain or snow. In its absence live stock cannot be maintained on the farm without undue expense, and consequently mixed farming will be impossible. Without a grass crop true rotation is not possible without great expense, for one cereal following another does not rest or restore the land, unless the cereal is a leguminous plant. Beyond all question grass is king among the crops of the farm in the United States and so it will continue to be."

Hay and Pasture Crops. — Members of two great families of plants are grown for hay and pasturage, the grasses and the legumes. Of the grasses *timothy* is the most valuable and the most widely cultivated for hay. Two other hay grasses well known in the Dakotas and Canada are
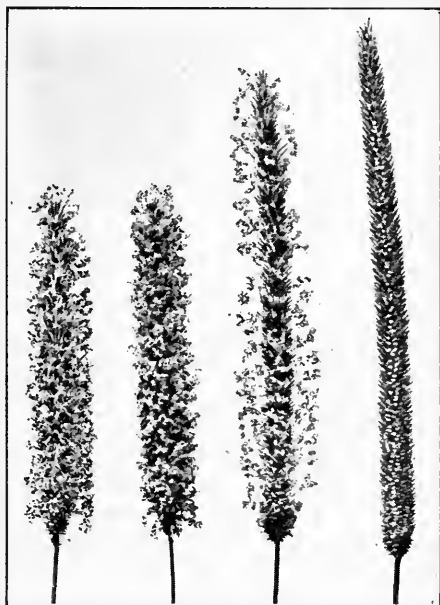
FIG. 114. — Timothy.

the *Russian brome* grass and *western rye* grass. *Kentucky bluegrass* is important for pasturage in a large part of this country, but little used for hay. *Johnson* grass is the best hay grass of the southern states, but is a very objectionable weed in tilled land, while *Bermuda* grass forms their best pasture sod and also makes good hay when grown in rich land. *Quack* grass, a persistent grower, should never be sown, for it is hard to eradicate it after it once gets started. *Sorghum* is a hardy giant grass that is grown both for sirup and for hay.
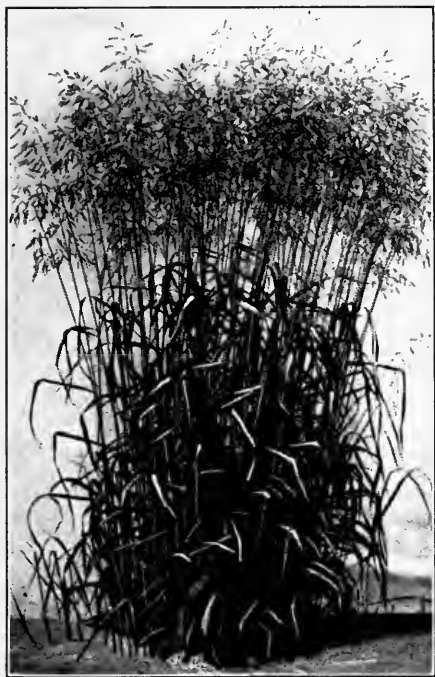
FIG. 115. — Brome Grass.

Millet in several varieties is frequently grown for hay. Of the legumes *red clover*, *alsike clover*, and *alfalfa* form the most important hay crops, the first ranking next to timothy, with which it is often mixed as a producer. Alsike clover is grown on soil too rich or too wet or too dry for red clover to thrive. Its introduction east of the Mississippi has been followed by increased production and widespread popularity.

Sowing Grass. — It is imperative that the soil should be clean, firm, mellow, and moist before the seed is sown for the hay crop; but if hay is grown on land that produced corn or potatoes the year before, the land need be only disked and harrowed, not plowed. The sowing, which is generally broadcast, may be done in early autumn or early spring, the former method producing grass that is better able to endure summer droughts.

It is quite common in many sections to sow grass seed with a nurse crop. This may be any one of the cereals. When alfalfa, for instance, is desired as a crop, it is often sown with beardless barley in the spring. The barley grows more rapidly

FIG. 116. — Blue Grass.

than the alfalfa, acting as a protector to the delicate alfalfa plants against the extreme heat of the summer and occupying the ground so that early growing weeds will be crowded out. When the barley is in the milk stage, it is cut for hay, and the alfalfa plants then grow thickly in the stubble.

Mixed Grasses. — A few grasses thrive best when planted alone. Among these are alfalfa and western rye grass. Timothy is often grown alone because of

its high feeding value for horses, due to its composition
and cleanliness, and because it stands shipping well, but
commonly it is
mixed with red
clover or alsike
clover. It is a
common practice
in the north to mix
red clover seed and
timothy seed and
sow them with one
of the small grains,
wheat, oats, or bar-
ley. The clover
grows quickly after
the cereal crop is
removed, often
making fine fall
pasturage. The
next spring, if con-
ditions are favor-
able, the clover
grows rankly over
the entire field.
After the clover is
harvested, the
timothy plants
that have been
held in check by
the rapid grow-

Fig. 117. — Millet.

ing clover come forward and make the hay crop for the
next year. Some clover may be grown with the timo-
thy, but as a rule the red clover is a biennial and its

roots die at the end of the second year. With one seeding and one preparation of the seed bed a cereal crop, one or more clover crops, and one or more timothy crops may be harvested.

There are three reasons for sowing hay in mixtures: 1. greater crop production; 2. wider adaptation of the mixed crop for feeding, owing to a combination of the qualities of the components; 3. easier curing of the crop.

FIG. 118. — Red Clover.

That the yield will be greater from a mixed seed can be seen when we consider that the different plants, having different depths of rootage, will occupy the soil more fully than either growing alone. Timothy is especially good for horses, clover for sheep and cattle. The mixture of the two gives a hay that is adapted for general farm feeding. The mixed grasses do not pack so closely when fresh cut, thus allowing the air to circulate in the bunched grass to produce a rapid curing.

There are other mixtures than the one mentioned above, the climatic and soil conditions of different areas determining what mixture will produce the best hay.

Legumes. — The great value of legumes in nitrogen fixation has been discussed on pages 113–114, but some of them have high additional value as crops, *clover*, *alfalfa*, and *cowpeas* being those that produce large quantities of good hay. The legumes are rich in protein, and protein is the food substance that makes muscle and milk; hence this substance in combination with those that produce heat and energy forms the food of a perfectly nourished animal.

Clover. — Red clover will grow on a poorer soil than timothy, but its best growth comes from a fertile soil rich in lime. It is extensively grown in northern and eastern parts of the United States, where it usually furnishes two crops a season. It should be harvested soon after the blossoms begin to turn brown, in order not to lose the leaves, which drop off when the plant becomes dry. Clover hay is dusty when not very carefully made, and is, therefore, not so good for horses, but it makes excellent roughage (coarse food) for sheep, cows, and young stock.

Alsike clover is adapted for growing on wet soils, and mixed with timothy it makes a better balanced and more palatable hay for horses than timothy alone. It is not a hairy plant as red clover is, and is therefore freer from dust.

Alfalfa. — Experiments have demonstrated that this legume, far from being confined to the western states for its productive area, can be grown successfully in every state in the Union. In the warmer regions it will, of course, grow more crops a year, but almost every part of the country can grow at least two crops.

Alfalfa prefers a deep, porous, somewhat alkaline soil, well stored with minerals, especially limestone,

but it will yield heavily on stiff, limy clays if well under-drained and manured, also on sand if well fertilized.

In short, the plant will grow in almost any soil that is treated to bring about the conditions it likes, but because of its deep rootage, alfalfa will not grow well on a shallow soil.

Advantages of Alfalfa. — 1. *It roots deeply in the soil.* This enables it to endure drought much better than other plants, and gives it a great extent of feeding ground.

FIG. 119. — Alfalfa.

2. *It is a vigorous plant*, therefore can begin to grow early in the spring. It continues growing throughout the whole season. The first crop is ready to be cut early in June, and a month later the second crop awaits the mower.

3. *It is richer in food elements and more palatable* than the other forage crops the farmer grows.

Inoculation of Alfalfa. — Sometimes farmers seem to have the right kind of soil for alfalfa, and yet the first crop is a complete failure. This is probably due to the fact that the soil has not been inoculated, that is,

bacteria without which the plant cannot thrive are absent from the soil. One way to inoculate the soil is to scatter broadcast over the field some soil from a successful old alfalfa field. If this is not practicable, bacteria cultures may be obtained from the Department of Agriculture and the seed inoculated.

Legumes as Forage Crops. — There are other legumes that, while not well fitted for hay because of being annuals, are yet exceedingly valuable for forage crops; that is, as green food for stock. *Crimson clover* is one of these which may be soiled; that is, fed green, or cut and dried and used for early feeding. Vetch, especially winter vetch, when sown with rye or wheat, is valuable for forage, as is also the *field pea* when sown with oats. The latter is especially good for milch cows if soiled and used for sheep when cured. The *soy* (soja) *bean* may be profitably used either for soiling or silage, especially in the south. In some western states it is fed on the land to hogs and sheep.

Vegetables and Fruits

Under the general name of vegetables are included those plants used for *culinary* purposes which are cultivated in the gardens. They may be conveniently classified, according to the part of the plant used, into tuber, bulb, root, seed, and leaf plants.

Tubers. — A tuber is an underground stem. (See page 131.) The only tuber that is used for human food in this country is the common potato. The Jerusalem artichoke is a tuber much used as a vegetable food in some countries, but it has never found great favor in the United States.

The Potato. — This vegetable, whether grown in

the garden for family use or in fields for the market, requires deep preparatory spring plowing of the soil, especially in regions where the rainfall is not great. The soil which the potato likes best is a sandy loam.
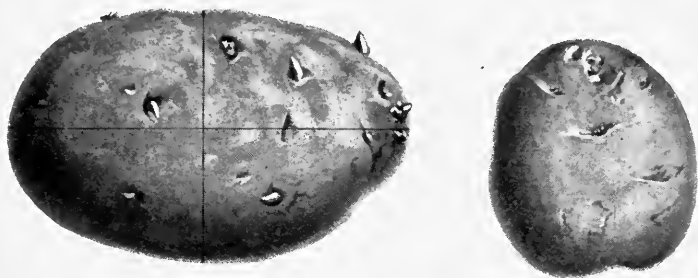
FIG. 120. — Potatoes.
The lines show how potatoes may be cut for planting.

Potatoes which follow alfalfa or clover crops in rotation show the largest yields.

Tubers are propagated by means of the buds (eyes); before planting, potatoes are cut into pieces, each having two or more buds. Experiments do not show that the size of the original seed potato affects the crop, but the type does; that is, buds of small potatoes will produce as large potatoes as those from large ones, but buds from deformed, rough, imperfect tubers will not bring satisfactory results. As a rule, the most successful potato growers do not care how small a seed potato is, providing it is perfect in form and true to type.

If potatoes that are to be planted are well washed and kept in a lighted room at a temperature of 45 degrees to 70 degrees for five or six weeks before planting, the sprouts will begin to grow. If then they are cut into pieces two or three days before planting, and placed in shallow piles so that they will not become heated,

the cut surface will become somewhat dried, and when planted the seed will not be so apt to rot.

Cultivation should closely follow planting. It should follow each heavy rainfall as soon as possible, so that the weeds may not get a start. Potatoes are cultivated from three to five times, according to the season and the rainfall, until the vines so fill the spaces between the rows that it is no longer practicable to go through them with the cultivator or team. If the potato field is not kept free from weeds and a good surface mulch is not maintained, no great yield of the crop need be expected.

In regions where irrigation is necessary, water is turned on whenever conditions seem to require it, whether to sprout the seed or to supply moisture necessary for steadily continued growth. After the use of water has been begun, the soil should never be allowed to become parched and dry to the end of the growing season. Experience has shown that a field of potatoes having once been stimulated by the artificial application of water must be watered frequently to avoid a setback in growth, for a check in the growth of either a plant or a tuber after once irrigated is more injurious than if the plant had lacked sufficient moisture continuously.

When the tops of the potato vines are dead, the crop is ready to harvest. In these days of farm machinery field potatoes, when grown on a commercial scale, are seldom dug by hand, because of the great expense of hand labor. One man with two good teams can easily dig six acres a day with a potato digger and with less injury to the tubers than results from ordinary hand digging. The soil should not be wet when potatoes are

to be dug, either in the field or garden, as too much of it will adhere to the tubers. They should be left on the ground only long enough to dry the surface thoroughly and should then be stored in dry, cool cellars in bins which allow a free circulation of air.

Maine leads the other states in the average yield of potatoes an acre, her crops showing an average of 175

Fig. 121. — Digging Potatoes.

bushels, but Wyoming, California, and Florida are not far behind. In regions where the farmer's entire dependence for moisture is the rainfall, the average yield for two successive years may vary widely. For instance, in 1904 Wisconsin's average potato crop an acre was 126 bushels, which dropped to 68 bushels, or only about half the yield in 1905, a dry year. Michigan, Minnesota, Illinois, and Nebraska showed a corresponding decrease.

Varieties of Potatoes. — There are many varieties of potatoes used in different parts of the country. New varieties are being originated every year, and many of the old varieties are discarded in some sections because they have ceased to yield well.

One of the most widely known varieties is The Rural New Yorker No. 2, also called Rural. It is a medium large, flattened, short, elliptical, white tuber with an even surface and rather few, shallow eyes. It is a late variety. Very similar to it are the Sir Walter Raleigh and Carmen No. 3.

The Cobbler potatoes, or Cobblers, are very often quoted in the markets. They are a white, roundish potato with eyes medium in number and fairly shallow. This is a very early variety.

Eureka Extra Early, Noroton Beauty, and Red Bliss Triumph are somewhat similar to the Cobblers.

The Early Ohio is an elliptical, plump variety. The eyes are rather numerous and fairly deep. It is a standard, early variety, and is considered one of the best for general planting.

The Burbank and Pingree potatoes are rather long, white potatoes, and are among the most popular of the late varieties.

The Pearl, also called the Wisconsin Peerless and the White Victor, is one of the best varieties for large yields. It is a medium early, white, netted, somewhat flattened, round to oval potato.

Roots. — The common garden root crops are *turnips*, *rutabagas* (Swedish turnips), *carrots*, *parsnips*, *sweet potatoes*, and *beets*. Some of these, namely turnips, rutabagas, and carrots, are also grown for forage crops in Europe, but not so much in this country.

Root crops in general require a rich, mellow loam, well supplied with potash, lime, and nitrogen. This initial fertility must be supplemented by good drainage and thorough cultivation, or a poor growth will result.

The root crops are biennials; that is, the plants store up a rich stock of food in the root the first year, which is used the following year in developing seed stalk and seed. Gathered the first year, the roots form a palatable food both for man and beast.

The common white, or English, *turnip* is so rapid a grower that it is often planted following early potatoes or peas, but it does not keep well. It is valuable as a forage crop for sheep. *Rutabagas* are larger and hardier than the common turnip. They are also used for feeding stock.

Carrots are grown more extensively as a food for horses than as a vegetable for table use, but still few farm gardens are thought complete without at least a row of these roots. The plants are tiny at first and very slow growers, hence their productive cost is comparatively large. To raise good carrots a light, mellow, deep soil is required, thoroughly free from weeds.

Parsnips thrive in the same kind of soil that carrots do. Having a deep rootage system, the plant is a deep feeder and is proportionately hard to harvest. This probably prevents its wide use as a stock food, although it has been found to be especially good for milch cows, increasing both the quantity and the quality of the milk.

The *sweet potato* requires a long, hot season and a thin, loamy soil, not very rich. The sweet potatoes are laid close together in a bed in early spring, where sprouts and roots soon form. When the former are a few

inches above the ground, they and their roots are separated from the sweet potato and set out in the field or garden, two feet apart in rows four feet apart. A second growth of sprouts will soon spring from the same sweet potatoes, and these are also transplanted. The sets in the field are also cut and transplanted as soon as the vines have grown to be about twelve inches long, a small number of sweet potatoes thus serving to stock a considerable area. Sweet potatoes require the same careful cultivation, manuring, and clean soil that potatoes need. Good crops show a yield from 200 to 300 bushels an acre.

Beets are of two varieties, the mangel-wurzel and the sugar beet. The former are used largely for stock food. As they require a rich loam, manure must be

FIG. 122. — Mangel-wurzels.

freely applied. Potash seems to have a favorable influence on the crop if applied in the fall so that it shall have worked deeply into the soil. Mangels must be thinned out while young, so that they may have room to grow. Sugar beets are grown for use on the table, but the development of the beet sugar industry in the United States has made such rapid progress in the past fifteen years as to make the garden crop of comparative insignificance. For use as a vegetable the seeds of this beet should be planted in rows one foot apart, one inch apart in the row, and one inch deep. When the plants are well up, thin to four inches space between them.

Note. — The so-called beet seed is really not a single seed, but a collection of three seeds, more properly called *beet fruit*. Efforts to develop a beet that shall produce fruit with but one fertile seed is meeting with some success.

Bulbs. — The *onion* is the only bulb that is of any importance as a vegetable.

The onion grows well in a moderately light loam. A clean soil for planting is necessary if the cost of cultivation be kept at a reasonable figure. Onions may succeed themselves on the same soil for successive years with less evil results than most other crops. If grown in a rotation system, they follow potatoes or carrots well. Very careful preparation of the soil followed by cultivation and heavy manuring or fertilizing with plenty of lime bring a yield from 800 to 1000 bushels an acre, a crop that is usually quite profitable. Hand labor is absolutely necessary to successful weeding, but such a large yield from a small area is secured as to make the culture pay. Onions are harvested by pulling as soon as the tops have fallen over and have begun to

die. The bulbs must lie on the ground until the tops are entirely dead. Experts differ as to the advisability of removing the dead tops before storing the bulbs, but in either case they must be kept in dry, cool places where the air can circulate freely.

Fig. 123. — Harvesting Onions.

The onion is very nutritious, containing a large quantity of nitrogenous matter and sugar with an acrid volatile oil resembling oil of garlic. This oil is dissipated in boiling so that boiled onions are much milder than raw ones. In warm countries this vegetable is of a more delicate flavor than in temperate regions. In Spain and Portugal a raw onion is often eaten like an apple, and with a piece of bread often forms the dinner of a working man. Bermuda and Spanish onions are among the choicest varieties.

In recent years the culture of onions for the market has often been through seeds sown in hot beds and transplanted when the young plants are three or four inches high, this method making it possible to grow some of the more delicate imported varieties.

If onion seed are planted so thickly in a poorly fertilized bed that the plants fail to make more than a start in growth, a small bulb is formed called an onion set. Onion sets are planted for early young onions in the spring. In some varieties sets are also formed at the tops of onions instead of seeds.

Seed Vegetables. — The garden vegetables grown especially for their seeds are the two legumes, the *pea* and the *bean*. Good corn soil is good pea and bean soil; it does not need extensive manuring. Very poor soil will often produce a fair crop, and such soils are always improved by growing these legumes, but to produce a good crop may require a fertilizer containing phosphorus, potash, and lime. The pea is a climbing annual, and the garden variety usually requires stakes or strings for support, but there are dwarf kinds that succeed very well without stakes. They are sown in rows from two to three feet apart.

Peas and beans for canning are grown in areas adjacent to factories, the whole plant being harvested and then passed through a viner, either on the farm or at the factory.

Leaf Vegetables. — The *cabbage* plant stores food in its leaves, which becoming thickened, and arranged in overlapping layers about a center form a *head* which furnishes a food for table use or a valuable forage crop. Cabbage seed for the garden or market crop is usually planted in a hotbed, and the young

plants later set out in rows in deep, rich, moderately
heavy loam with a good moisture-holding capacity.
Lime is excellent for the growth of this vegetable, but,
when it is absent, suitable manuring will bring large
returns. Disease is sure to attack the plant if the soil
is not well drained and rotation practiced, for cabbage
cannot profitably succeed itself or any other member of
its own family, such as common turnips, rutabagas, or
cauliflower. Liberal quantities of other than hog ma-
nure are beneficial if plowed in either in the fall or early
spring. In order to avoid the ravages of insects, among
which the cabbage has many enemies, cabbage must be
kept constantly growing by frequent cultivation. Cab-
bage may be left in the open until the temperature is
only a little above the freezing point, and when har-
vested must be put in a cool, dry place to prevent
decay, either in a cellar or in shallow ground pits.

Fruits. — The fruit of the plant is the ripened ovary,
or seed vessel, with its contents and whatever parts are
consolidated with it. A general classification into *tree*
fruits and *small* fruits will be found as convenient as
any, the latter including all fruits grown on small
shrubs, low plants, and recumbent or climbing vines.
The common tree fruits of the temperate regions are
the apple, pear, peach, plum, and cherry; of warmer
regions, the citrus fruits, orange, lemon, and grape-
fruit. The common small fruits are the strawberry,
raspberry, blackberry, the currant, the grape, the to-
mato, and the melons.

Nuts are fruits with a hardened outer covering, or
shell. Few farmers pay any attention to their culture
except in the warmer regions where peanuts, almonds,
pecans, and the like are raised.

Growing a Fruit Tree. — When we plant a seed of a certain variety of plant, we naturally expect that seed to produce a plant of the same variety, but experiments have proved that in the case of the tree fruits, at least, planting the seed of a given variety may produce a tree that bears fruit of an entirely different variety. More than likely the fruit of an apple seed will simply be an inferior variety, of no value at all as a fruit. Trees grown from seeds are called seedlings. Orchardists who are trying to develop new and improved varieties grow a great number of seedlings in the hope that out of the large number there may be found one or more trees bearing fruit that is an improvement over the varieties now in existence. It is through this process that the existing varieties were found.

Tree fruits are ordinarily grown on land set aside for that purpose, called orchards. The small fruits are commonly cultivated in gardens.

Location of an Orchard. — In a hilly country orchards are planted on all sides of the hills, but in the higher latitudes the north side of hills is preferred, as that slope is not subject to so many variations in temperature. A location should be secured that is not subject to frosts during the growing season. Orchards should not be planted in hollows or closed valleys because of lack of cold air drainage. As the warm air rises and the cold air descends, the cold air may be pocketed in the hollow unless there is a still lower hollow or valley that may drain out the cold air.

Proximity to a body of water has a tendency to equalize the temperature of the surrounding land and will often avert untimely frosts.

Arrangement of Trees. — The most common method

of setting out orchard trees is to set them in squares. This, however, is not the best system with reference

to the use of land. If the roots and branches spread out uniformly from the point of planting, it is evident from observing Figure 124 that the land in the center of the square outside of the circles is wasted. Some have attempted to use this waste land by planting a tree in
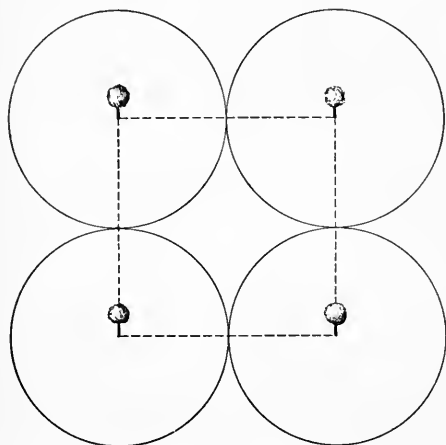
FIG. 124.

the center of each square. When this is done, the trees are too crowded, as is shown by the overlapping of the circles in Figure 125.

The hexagonal system (Fig. 126) uses the land more economically. The trees are distributed evenly over the area, and there remains but 10 per cent of unused land.
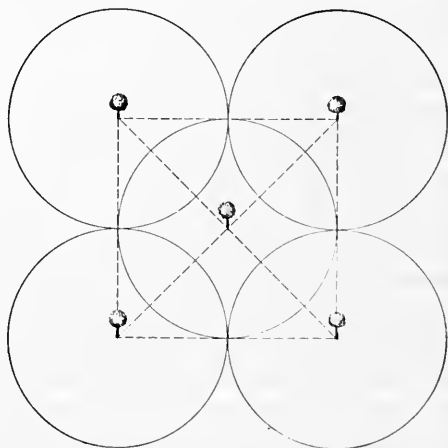
FIG. 125.

If trees are planted thirty feet apart, the square system will give forty-eight trees to the acre, while the hexagonal system allows fifty-five trees to the acre.

Planting an Orchard. — Few farmers raise apples or other tree fruits from the seed. They depend instead upon the nurseryman to supply them with trees from two to three years old. Symmetrical trees with roots in good condition should be se-
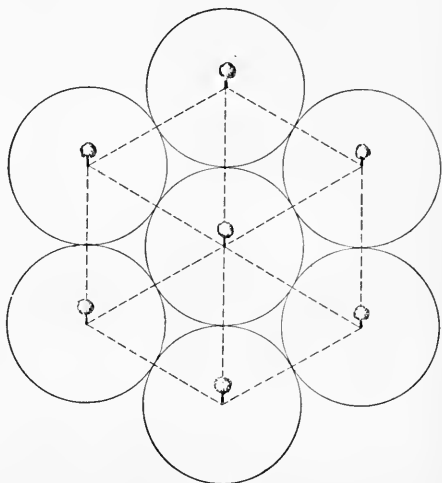
FIG. 126.

lected, but perfect roots are more important than symmetry, for pruning can remedy some defects in shape. Horticulturists are recommending less top and more roots on transplanted trees, on the principle that roots can grow a top, but a top can never do the work of roots in the growth of the tree.

Orchard land should be well plowed and harrowed before being planted, and well tilled afterward. Farmers have learned that an orchard must not be left to take care of itself.

The holes for planting should always be greater in diameter than the spread of the roots, so that the root tips need not be coiled or doubled back.

The soil should be closely packed under and about

the roots and left loose on the surface so that moisture may readily penetrate to the roots. Trees should be set far enough apart so that each tree may receive the necessary soil space for the moisture needed, and space

FIG. 127. — Planting Fruit Trees.

The notched board placed over the hole dug to receive the tree enables the planter to keep the trees exactly in line when set.

for the branches so that it may not be deprived of sufficient sunshine.

Note. — A method of planting advocated by H. M. Stringfellow of Texas is at variance with the accepted practice, but under many conditions good results are secured. The method consists of the following points :

1. Prune both top and root very closely so that the tree looks much like a walking stick.

2. Plant in small holes with the soil packed and jammed hard about the roots.

3. Prune little, if any, till the tree comes into bearing.

4. After the tree comes into bearing, do not cultivate, but mulch by cutting such grass and weeds as grow about the trees and piling it over the roots thickly. Manure and straw may also be hauled on for mulching.

Care of an Orchard. — *Crops in the Orchard.* The old practice of sowing some other crop in the orchard or letting the ground grow up to grass or weeds is seldom followed by successful fruit growers. It is true that before the

FIGS. 128, 129. — A Well-pruned Orchard (above); an Unpruned Orchard (below).

trees have an extended rootage, that is, while they are from two to five years old, low-growing crops like potatoes and cabbage, or small fruit like tomatoes, may be raised in the orchard with no
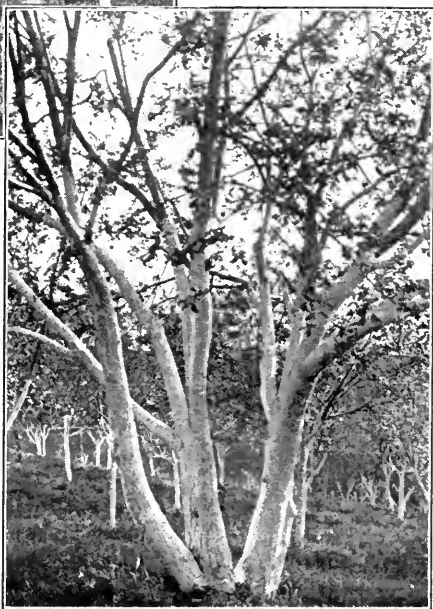
damage to the trees, if not planted too near them. Grass and weeds are injurious to the young orchard, except, perhaps, a crop of clover or soy beans, sowed late in the summer as a cover crop and plowed under in the spring. Care should be taken not to injure the roots.

Note. — Although the largest number of successful orchardists cultivate their orchards and keep all growth of grass or weeds out of the orchard during the summer, some have achieved notable success by allowing sod to form and doing no cultivation. To conserve the moisture and to fertilize the trees a heavy mulch of hay, straw, or weeds is placed about the trees and is kept there at a depth of not less than four inches. The mulch should be spread out as far as the branches extend.

Pruning. Judicious pruning is important for six reasons: 1. It checks growth and this increases fruitfulness. 2. By thinning the fruit, thus reducing the quantity of the fruit allowed to be borne by the tree to the capacity of the tree, the quality of the product is improved. 3. It aids in controlling some of the most dreaded plant diseases. 4. It makes cultivation easier by removing the branches near the ground. 5. It allows the sunlight to get at the fruit, giving a better color to it. 6. It regulates the head of the tree so that harvesting the fruit is made easier.

Root and top pruning, when transplanting takes place, is also practiced, the mutilated and dead root branches of the sapling being removed, and most, if not all, of the top. Care must be taken in all pruning, no matter when done or whether to roots or top, that a smooth, clean surface is left, or injury to the tree may follow.

Branches of considerable size should be cut close to the trunk or to the larger branch from which they grow,

so that no stubs are left. The cut should be made with a fine-toothed saw, and the cut on the tree should be covered with grafting wax to prevent rotting and to encourage healing of the wound.

To prevent stripping the bark from the tree, the branch should be sawed from the under side part way through the branch first, then completed by sawing from the upper side.

Smaller branches may be pruned with a sharp knife, cutting upward.

Standing trees which run to branches and foliage instead of flowers and fruit are sometimes root-pruned to encourage bud formation. This is done by digging a circular trench around the tree from three to six feet from the tree trunk, cutting off all the roots encountered. The soil is then returned to the trench and packed firmly.

Pruning for Fruitfulness. — The chief object in pruning orchard trees that are in bearing is to increase the production of the best grades of fruit. There are certain principles that should be observed if the orchardist wishes to accomplish this end:

1. The fruiting habit of the species or variety should be studied and thoroughly understood before pruning is attempted. He should know where the fruit buds grow and when they are formed.

2. Pruning should stimulate the normal growth of fruit buds well distributed over the branches.

3. Since the parts of the tree that grow the most rapidly usually produce the least fruit, pruning should check the rapid growth of parts that are expected to bear fruit buds.

4. Since the rapid growth of any particular part of

a tree depends largely on the amount of water it receives from the roots, and since frequent branching diverts the flow of sap, it follows that the part of the tree that is divided by much branching is most likely to produce fruit buds. Long, unbranched sprouts (except in some cases the leader) should be cut back. Branches should be thinned sufficiently to admit light and air.

5. Some new wood should be allowed to grow each year to produce a new crop of buds, but a small amount of growth upon all the branches should be the aim.

Time of Pruning. — If pruning is not too severe it may be done at any time. It is better, however, to prune systematically twice each year. The largest part of the pruning should be done while the tree is dormant in the winter or in the early spring before the sap begins to flow. Summer pruning should be performed before the shoots are covered with foliage. In the spring very often a number of sprouts will shoot out from the trunk or from the large branches. On the mature tree these should be rubbed off as soon as discovered. Other shoots that are not located favorably may at this time be cut off. New growths that are properly placed and are growing in the right direction may be growing too long. Such should be pinched back to retard their growth.

Note. — The older method of trimming trees allowed the heads to form high in the air. The trunk was long enough to enable horse cultivation to come close to the tree without interference with the lower branches. The disadvantage of this method is that the cost of harvesting the fruit is much greater than if the head were closer to the ground, and the fruit that falls from the high trees to the ground is bruised and usually spoiled. The later method of trimming produces

a low-headed tree reducing the cost of harvesting and making the injury to windfalls much less. The low-headed trees are also more economically and thoroughly sprayed.

The Apple. — Because the apple tree is hardy, bears well, has many varieties, both early and late, and the fruit bears shipment well, the apple is the cheapest and most widely known of the temperate fruits. It thrives in nearly all of the northern states.

The apple likes a rich clay loam stocked with lime, but it does well on a variety of soils if well cared for. Saplings two or three years old are generally considered best for planting. They will produce fruit in from two to

Fig. 130. — Picking Apples.

ten years, depending upon the variety. The time of maturing and the keeping quality depend upon the variety of apple and the climate in which it is grown. Winter apples of the northern states are early autumn apples when grown in Georgia. Many excellent apples in one part of the country have little value in another part where conditions or climate are different. It is therefore safer to purchase nursery stock from nurs-

eries in the same latitude and having the same conditions of climate and soil as the orchard to be set out. Apples will keep better if hand-picked, packed in barrels, and stored in a place just above freezing point.

The Pear. — Clay soil if well drained and not over-rich is favorable to the growth of this fruit. The pear is nearly as hardy as the apple, so far as cold is concerned, but it is especially liable to a disease called fire blight, which disease attacks it in certain localities, thereby restricting the range of profitable cultivation. Propagation by budding is commonly practiced with pear trees. Trees may be set somewhat nearer together than the apple trees, 15 to 20 feet apart, as they do not have such widespreading branches.

Potash is better for the pear orchard than manure rich in nitrogen, for the latter induces luxuriant growth, and this is favorable to the bacteria that cause fire blight. For the same reason pear trees require less cultivation than other fruit trees.

The Quince. — This fruit, unlike its relatives the apple and pear, is not edible in its raw state, but makes excellent jelly, marmalade, and the like. It is an irregular-growing tree or shrub attaining a height of about 10 feet. It grows farther south than the two preceding, not being able to thrive in the colder regions. This tree is often used as a stock upon which to graft the pear, but is itself usually propagated by layers or cuttings. (See pages 155 and 158.) It takes from two to twelve years for the quince to reach its full bearing capacity.

The Peach. — The peach grows best on well-drained, sandy loams in the warmer regions, but farther north it does better on a well-drained clay loam. A peach orchard must be well plowed and harrowed, the trees

being set from eighteen to twenty feet apart. The great peach-growing states are New Jersey, Maryland, Georgia, Delaware, Michigan, Colorado, New York, Connecticut, California, Oregon, and Washington. This shows a wide climatic range, but peaches, owing to their great susceptibility to cold, are the most uncertain fruit crop raised. A few overwarm days will cause the undeveloped buds to begin to swell, and then the cold or frost blights them and the crop is ruined.

Cotton and potatoes are often grown in the young peach orchard in the south, the cultivation necessary to these crops helping the trees.

The peach is usually budded (see page 163) on its own seedling, for the production of which the pits are stratified and then planted.

The Plum. — This tree is native in central and northern United States, where the use of the cultivated varieties for culinary purposes has much increased in recent years. But we still have to rely largely upon European and Japanese species for our dessert plum. The production of hybrids through cross-fertilization with the foreign plums is introducing some new American types that are proving valuable.

The *American plum* is the species found growing wild in our woods. Nurserymen have made selections from this and have developed some desirable plums. Cultivation improves both the size and the quality.

The *European plum* is the original plum. The more common blue and yellow plum of the markets and the dried prunes are from this species. It is the most extensively cultivated of the plums, but is not hardy in the northern Mississippi Valley.

The *Japanese plum* has been widely disseminated in

North America, and although the fruit is not of the best quality, hybrids of this species with others have produced some very promising varieties.

Other species are the *Chickasaw plum* and the *Wild Goose plum*, of which the *Miner plum* is a popular variety.

Plum trees will bear fruit the second or third year after planting. The plum as well as the cherry and peach is propagated by budding or by grafting.

Suckers grow from the roots of the plum tree, and when these are from trees that are not grafted they may be removed with a part of the root and replanted. This is probably the best method of propagating plum trees on a small scale.

The Cherry. — There are two chief varieties of this fruit, the sweet, or English, cherry and the red, or sour, cherry. The former is a good dessert cherry, but is not hardy enough to have a wide range. The latter is the common pie cherry of the Mississippi Valley and northern United States. Both species are propagated by budding, grafting the cherry being rarely successful. Heavy, wet soils are very disastrous to this tree. A grass crop is not injurious if cut often and used as a mulch.

The Citrous Fruits. — No family orchard in California can be considered complete without at least one or two of the citrous fruits, such as oranges and lemons. These are known as semitropical fruits. In America they can be grown with profit only in California, Florida, and the delta region of the Mississippi River. This limited range makes a good market for the product when raised on a commercial basis. In addition to the fruit to be harvested from them, the trees them-

selves are quite ornamental, and they also afford abundant shade, being often grown for these purposes alone.

The Orange. — The orange can be grown in California with greater profit than any of the other citrous

Fig. 131. — Orange Grove.

fruits. Though its production is chiefly confined to the southern part of the state and the Sacramento Valley, yet there are doubtless small regions elsewhere in the state well adapted to the growth of this fruit.

The chief determining factors are soil, elevation, and exposure. The orange prefers a deep, rich, mellow soil, though it will thrive in nearly every kind of fertile soil. The orchard should be protected from winds by a grove of trees where the relief of the land does not afford natural protection. Though irrigation is not always necessary, the trees must be supplied with plenty of water.

Pruning should be done at some time during the season while the tree is dormant. Only those branches

which are dead and those which have passed usefulness should be removed. There is great danger of cutting away too much. Care should be taken to preserve the natural outline of the crown, as both fruit and leaves are borne at the ends of the branches. The orange is propagated by budding. After two years of growth in the nursery it is set out in the orchard and usually commences to bear five years after planting.

The navel orange, a seedless variety imported from Brazil, is especially adapted to California conditions, but will not thrive in Florida.

The ordinary sweet oranges of the markets grow on trees 25 to 30 feet high. Seedlings of this variety are subject to *root rot*, and on that account it is usually budded on a stock of sour or bitter orange which is not subject to this disease.

The Satsuma orange grafted on *Citrus trifoliata* can be grown successfully even in parts of southern states subject to killing frosts.

The Lemon. — This tree will thrive in a variety of soils, though a sandy loam is preferred. While the lemon does not require the high temperature necessary to produce the best qualities in the orange, it will not, at the same time, bear such low temperatures as the orange. Since the orange root will thrive in a greater variety of soils than will the root of the lemon, it is quite common to graft the lemon on an orange seedling stock. Owing to its spreading habit, the tree must be carefully pruned. If this is not done, the fruit will be borne at the ends of the long, willowy branches and necessary cultivation will be rendered impossible.

The Grapefruit is now extensively grown in California and Florida. The botanical name is *pomelo*, but

owing to its growing in clusters, it is commonly called *grapefruit*. It requires about the same conditions and culture as the orange, except that it demands a higher temperature, being slightly less hardy. Different varieties are propagated by budding on pomelo or orange seedlings. The Florida Experiment Station recommends the exclusive use of commercial fertilizers as they cause the trees to fruit more heavily, to produce a fruit of

FIG. 132. — Grapefruit.

better quality, and to maintain a healthier condition. Fertilizers should be applied twice a year, just before the commencement of growth and again in summer. Sometimes a third application in the fall is advisable, as the roots grow during winter seasons.

Berries. — *Strawberries*. Certain varieties of the strawberry commonly grown in the United States bear only pistillate flowers; that is, no pollen is formed in its blossoms. (See page 148.) This requires that some variety bearing pollen-forming flowers be set out with it, or no fruit will result. It has been found that one row of the latter to every three or four of the

former will furnish pollen enough to fertilize the plot. Of the pistillate varieties the following are very popular: Warfield, Haverland, and Crescent. Of varieties having both stamens and pistils, that is, perfect or bisexual, the following are among the best known:

Fig. 133. — Cultivating Strawberries.

Senator Dunlap, Jessie, Bederwood, and Wilson. Most fruit growers set out their plants in the spring, either in hills 3 or 4 feet apart, which allows the cultivation both ways, or in matted rows, which allows the cultivation only between the rows. The plants for the latter are set 12 inches apart, in 4-foot rows. As runners form, the row becomes a mass of plants. The ground must be very rich, preferably a sandy or clay

loam and highly cultivated. Successful growers seldom use the same ground more than three seasons. Being low growers, strawberries suffer much from weeds and droughts. Careful, clean cultivation is essential to success. Straw, leaves, or hay is used as a winter covering in cold regions.

Raspberries and Blackberries. There are four well-known varieties of the raspberry, the American red, the European red, the purple cane (a hybrid between the first and last), and the blackcap. A closely allied fruit is the blackberry. The American and the European red raspberry and the blackberry are propagated by root sprouts one year old, the last two by layering in early fall. (See page 158.) When the roots are well formed, the connection with the parent plant is severed, and the new plant is transplanted to a new bed, where the plants are commonly set $3\frac{1}{2}$ or 4 feet apart, in rows 6 or 7 feet apart. These berries like a sandy or clay loam, but less richness of soil than the strawberry. A clean soil is just as essential to successful culture. Second-year pruning is necessary in order to thin out the bushes, and each year-old and dead canes should be removed.

Gooseberries and Currants. Gooseberries and currants belong to a different family from the small fruits just described, as may be easily seen by noticing the difference in the way the seeds are borne. Propagation is by mound layering or cuttings, but the soil required is richer and moister than raspberries need. Free cultivation and mulching will make them respond liberally with fruit. There are three common varieties of the currant: red, white, and black.

The Grape. — Grapes require plenty of heat and sunlight, good drainage and a light soil for their development. Terraced, sunny hillsides are frequently utilized as vineyards in this country as well as in Italy. Our best varieties, the Concord, Worden, Catawba, Isabella, and Delaware, were developed by cross-pollination, but all are of American origin. Varieties grown in California when dried furnish the raisins of the market. European varieties such as the Tokay and Muscat thrive in California only. Layering, root grafting, and cuttings are commonly practiced as a means of propagation of grapes. The soil should be well prepared for the new plants, which are usually set 7 to 10 feet apart, in rows 7 or 8 feet apart, the distance being determined by the size of the variety. Three years later the vine will begin to bear fruit, always on the year-old stems, usually two clusters on each shoot. It follows that the ripened shoots, or canes, must be pruned each year in order that the strength of the vines may be conserved in the year-old fruit-bearing stems.

The pruning is done in the fall in cold regions, in the spring in warm regions. The remaining stems are supported upon trellises in this country, but in many European countries the vines are allowed to trail on the ground. Winter covering is necessary in the colder latitudes.

The Tomato. — Though commonly thought of as a vegetable and served on the table as such, the tomato is really a fruit. It may be planted in the open with considerable certainty of a crop, but north of the latitude of Washington the seed is sown in boxes or hotbeds soon after the first of March. The young plants are

transplanted to another box as soon as the first true leaves appear, set out in 2-inch squares. When they begin to seem crowded, they should be again transplanted in 4-inch squares and kept growing until near the last of May, when they may be placed in the garden 20 inches apart in rows about 18 inches apart. All side branches should be pruned as the plant grows and the main stem tied to a stout support about 5 feet high, as the plant will probably reach nearly this height. In Michigan the tomatoes have shown a yield as high as 1200 bushels an acre. Tomato growing as an industry has attained greater proportions in Maryland than in any other state in the Union.

Melons.—Both the muskmelon and the watermelon, while natives of southern Asia and Africa, thrive fairly well in northern latitudes, although not reaching the full luxuriance and rich flavor of the southern-grown product. The wire-grass region of Georgia is said to produce the best quality and largest crop of watermelons, while no section has succeeded in surpassing the famous Rocky Ford muskmelons of Colorado, although this variety is grown extensively in other parts of the United States. The three best known varieties are cantaloupe, nutmeg, and pineapple. The Rocky Ford melon is a nutmeg.

The muskmelon needs a deep, warm, sandy loam well supplied with humus. The seeds are planted in rows 6 feet apart and 1 inch deep in hills 3 feet apart. In Colorado irrigation is necessary. The most water is required about the time the blossoms begin to set well. When the plants have four leaves, they are thinned to three plants in a hill.

The south annually ships millions of watermelons to

the north, Georgia, Texas, and Missouri leading. Although this melon is raised also in the northern states, it thrives best on a rich, warm, sandy loam well supplied with humus. Hills are planted 10 feet apart. In northern latitudes the hole is made from 8 to 10 inches deep and filled two thirds full with rich, well-rotted manure; the soil is mixed with this until the hill is nearly full, then a small quantity of wood ashes and hen manure and a little phosphate are added. In the south the manure is spread on the field, not concentrated in the hill. Ten or twelve seeds are planted in a circle about 1 foot in diameter in the center of each hill and then covered with less than an inch of fresh moist soil. Deep and thorough cultivation is necessary at first, followed by more shallow tillage after the vines begin to run. In the north the fruit does not begin to ripen until August.

Note. — To make sure of early ripening, melons are often started under glass. Two or three seeds are planted in the center of small squares of sod packed closely together with the grass side down. The squares with the growing melon are transferred to the field or garden when the weather permits without injury to the plant.

CHAPTER V

PLANT DISEASES

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What is a Plant Disease? — It is not always an easy
matter to define disease either in plants or in animals. As
with human beings, so with plants, one cannot always
distinguish sharply a condition which may be called
healthy from a condition of slight indisposition. All
sorts of gradations between perfect health and a badly
diseased condition are possible, there being no sharp
line where one can say, "These are diseased and those
are healthy." For instance, thickly planted wheat
may result in a growth of plants that are not quite so
vigorous as wheat sown at the normal rate, yet the
plants may not be very noticeably diseased. They
are nevertheless not so healthy as those planted under
normal conditions. On the other hand, a rusted wheat
plant is clearly seen to be diseased. We give a defini-
tion as accurate as is possible when we say that when-
ever the ordinary functions of a plant are seriously
interfered with, the plant is diseased.

Cause of Disease. — There are many ways in which
plants may be injured. Mechanical agents of one sort
or another account for a good deal of damage. For
instance, hail, wind, and frost all contribute to a con-

siderable loss in plants. Gnawing and browsing animals may injure many plants, and insects cause an enormous amount of damage to plants and their products, many millions of dollars' worth of plant products being destroyed by them every year in the United States. These insect injuries may be merely mechanical, as when the foliage is eaten by caterpillars; galls or other deformities may be formed on the plants; or the life of the plant may be so interfered with by attack on a root system, for instance, that the whole plant dies.

A third class of plant injuries may be said to be physiological. When the conditions of weather, soil, or other natural surrounding factors are not quite normal, the plants may become sickly and even die. There are many such diseases which are clearly marked and which can, at the present time at least, be attributed only to some serious default in the environment of the plant.

The plants known as fungi constitute the fourth class of causes of injury and ordinarily the term plant disease is limited to this and the preceding class. Fungous diseases of plants are exceedingly common almost everywhere and are of enormous economic importance. One epidemic of rust caused a damage of probably more than ten million dollars in one year in three states of the United States. It is with the fungous diseases of plants that this chapter particularly deals.

Fungi. — First of all, it must be understood that the fungi are plants. Some idea may be obtained of the many kinds of fungous plants by enumerating a few conspicuous examples: the mushrooms, common mold of bread, mold of cheese, puff balls, the woody shelves

so often found on dead or decaying trees, the yeasts, the rusts and smuts of grains, mildews of grapes and potatoes, and the powdery mildews of lilacs and roses.
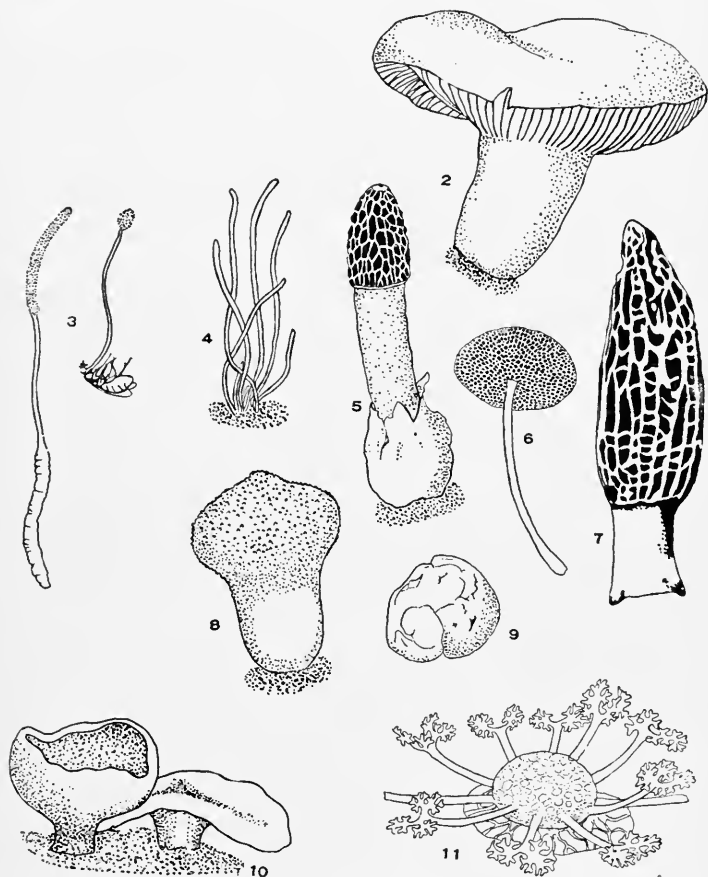
FIG. 134. — Varieties of the Most Common Kinds of Fruiting Bodies of Fungi.

2, a gill fungus; 3, caterpillar fungus, one on grub and other on fly; 4, club fungus; 5, carrion fungus; 6, pore fungus; 7, a morel; 8, puff-ball; 9, truffle; 10, cup fungus; 11, sacspore-capsule of powdery mildew (highly magnified). 2-8, after Engler and Prantl; 10, after Rehm; 9 and 11, after Tulasne.

Since the plants known as bacteria have at least similar methods of life and cause many diseases not only in animals but in plants, some botanists include them within the group of the fungi. These bacteria are among the chief agents of the diseases of man, such as tuberculosis, diphtheria, cholera, and many others.

Since the fungi are plants, it will be well to compare them with plants with which one is ordinarily acquainted, namely, the common flowering plants. The flowering plants may be called independent plants because they are able to manufacture food from the elements of the soil, and from air by the use of sunlight working on the green material, or chlorophyll. The most important and conspicuous difference, at least from our standpoint, between the fungi and the independent green plants, lies in the fact that the fungi do not possess any chlorophyll. This factor has a very deep meaning, namely, that the fungi are dependent, not independent, plants. In other words, they cannot manufacture their own food as the green plant does, but must derive at least a part of their nutrition from some other plant or animal.

There are two ways, in general, in which the fungi and bacteria may derive that part of their nutrition which they are required to get from preceding plants or animals. These two methods of sustaining life form the basis of a division into two classes. The first class comprises the parasites, which live directly on growing plants and derive their nutrition from these living plants. Well-known examples of this are smuts of corn and other cereals, and the bacteria which cause the diseases of man mentioned above. The second class of fungi consists of those which do not live on other living things, but which get their nutrition from the

dead and decaying remains of other plants and animals. In fact, they are responsible for this decay since they are the agents which break up the dead plant or animal body into simpler compounds and in so doing derive a certain amount of nutrient material. Good examples of this sort are the fungi which cause the rot of wood or the mold of bread and cheese. These fungi and bacteria are called saprophytes. In brief, then, there are two life habits: first, of parasites, which live on living things, and second, of saprophytes, which get their food from either dead plants or animals.

Life Story of a Fungus. — Although the most conspicuous difference between the fungi and flowering
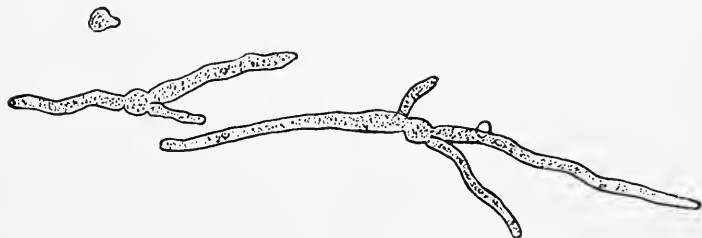
FIG. 135. — A Germinating Spore at Different Successive Stages of Several Hours Apart.

The small resulting mycelium is seen below. A caterpillar fungus (Cordyceps) spore. Highly magnified. (Minnesota Plant Diseases.)

plants lies in the lack of chlorophyll in the fungi, there are also other very great differences. Flowering plants are much higher types of organism than the fungi, just as man is a much higher type of animal than the horse. This difference is clearly seen when one studies the life story of the fungus. The fungus does not produce seeds. Its reproduction nevertheless may be fairly complex; in fact, one fungus may reproduce in a number of different ways.

In general the fungi reproduce by means of spores. Spores are very tiny, usually single-celled, somewhat spherical bodies often protected by a thick wall. They may be scattered by wind, water, insects, or in other ways just as seeds are distributed. Many of these spores are so small that it would take 5000 of them arranged side by side to make a line one inch long. When this tiny spore is blown, or carried in some other way, into unfavorable conditions, it is often able to resist such unfavorable conditions, as cold or dryness, until favorable conditions return. Then the spore commences to grow. It swells up and sends out a small protuberance which soon lengthens into a thread. This thread is known as a *hypha* (plural, *hyphæ*). The hypha elongates rapidly and may soon begin to branch. The branches grow and again branch so that in a short time a dense network of threads, or hyphæ, may be built up. These threads are so constructed that they are well fitted to absorb a large amount of material. In form and power of absorption they are similar to the root hairs of the flowering plants. The whole mass of threads which is engaged in absorbing nutrient material is known as a mycelium. The mycelium after growing for some time may send up special threads, and on these special threads the spores are again formed.

The two important parts, therefore, of the fungous plant are the mycelium and the spores. The spores and mycelia may differ very widely in different fungi, but all fungi have some sort of spore and some sort of mycelium. Rust spores, smut spores, mold spores, and spores of the blight are very different from one another when seen under the microscope, but they all produce in general the same results; namely, they

scatter the fungous plant or preserve the plant through the winter, or other unfavorable seasons.
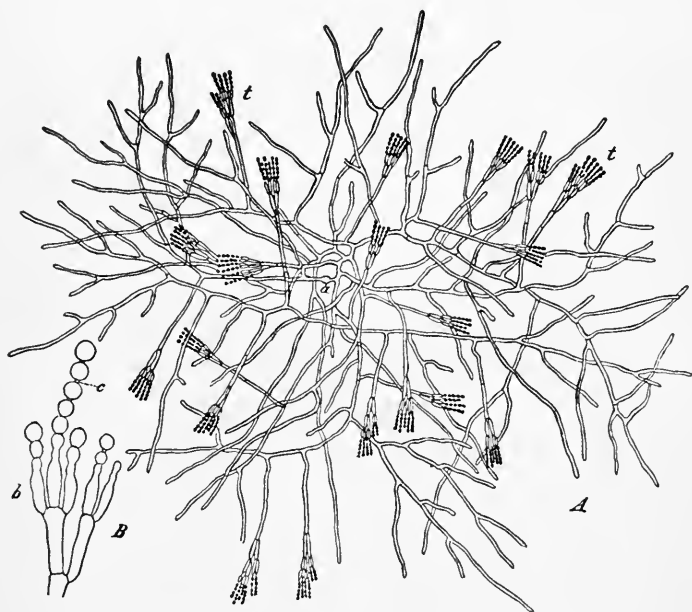
FIG. 136. — The Mycelium of a Food-mold Fungus (Penicillium).

A, mycelium which is entirely absorptive and tufts (t) of spores (reproductive tract). The original spore from which the mycelium grew is seen at a. B, highly magnified view of spore tuft. (After Zopf.)

The life stories of the fungi also differ greatly. Smut has a very different history from rust, and rust, again, has a very different life story from the blight. It cannot be too strongly pointed out that the life story of each disease-causing fungus must be accurately known before anything can be intelligently done to fight the disease. For instance, in the case of smut, the spores, which appear as the smutty mass in the

wheat head get on the mature grain at harvest time and cling to the grain through the winter. They are planted with the grain in the spring. When the grain commences to sprout, the smut spore commences to
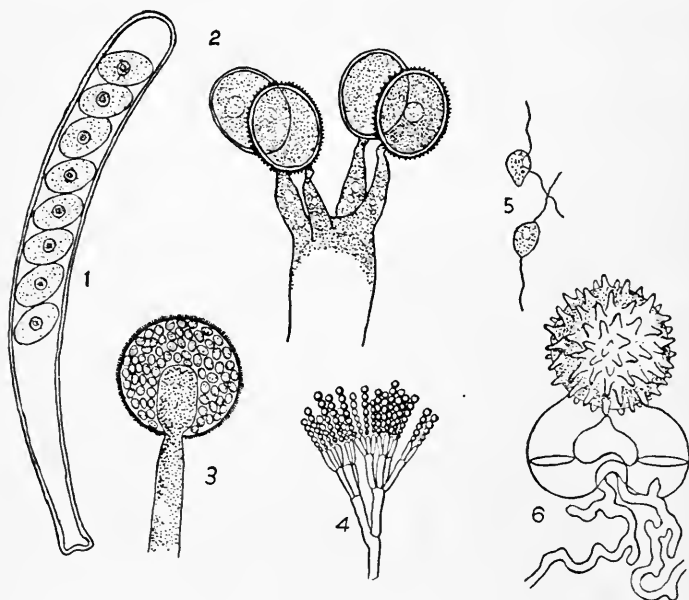
Fig. 137. — Spores of Fungi.

1, sack with spores; 2, basidium and spores from a mushroom; 3, spore case of mold containing numerous spores; 4, tuft of pinched-off spores of blue mold; 5, swimming spores of an algal fungus; 6, spore of a black mold produced by a breeding act — stalks of the breeding cells are seen below the spore. 1, 2, and 5, after DeBary; 3, after Sachs; 4 and 6, after Brefeld.

sprout and the hyphæ, or threads, make their way to the inside of the grain plant. They stay inside of the plant and grow up with it until the wheat plant heads out, when the parasite inside fills the kernels with its threads and then forms spores again. Now with a knowledge of this life history it can readily be seen that
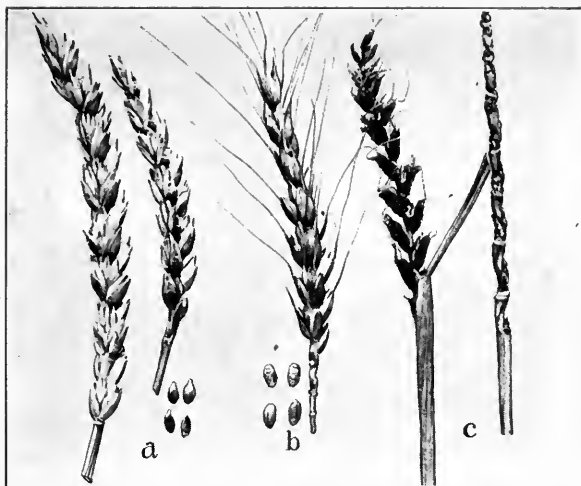
a, bunt or stinking smut of wheat (Fife); head to the right with glumes removed to show smutted kernels (smut balls) in place; two whole and two broken smut balls shown below; *b*, a sound head of wheat (Minnesota No. 188), with sound grains shown below; *c*, loose smut of wheat (Minnesota No. 188); to the right a head from which all of the spores have been blown, leaving the bare stock.

d, two heads of covered smut of barley (Minnesota No. 105); *e*, a sound head of barley; *f*, loose smut of barley; to the right a head from which the spores have been blown.

FIG. 138. — Smuts of Cereals. Heads of Wheat and Barley showing the Common Smuts. Bul. 152, B. P. I., U. S. Dept. of Agric.

the easy place to attack this smut is when the spore is clinging to the seed. It is therefore possible to kill the smut by washing off or killing the spores on the outside of the grain. Hence, seed treatment as described below will cure this disease. In all cases the life story of the disease-causing fungus is an important thing. It is the main object of this chapter to bring before the student the relationship between these life histories and combative measures which will give a basis for the intelligent handling of plant diseases in general. With this in view four types of diseases will be described, each type demanding a different kind of treatment. The reason for the treatment in each case will be shown to depend on the life story of the disease.

Some Common Diseases of Plants

Smuts — Seed Treatment. — Smuts constitute one of the most common and destructive groups of fungous diseases. The damage in the United States to cereals alone reaches many millions of dollars, and other crops may also be attacked. Every farmer is familiar with smut in wheat and oats, and everybody is familiar with the large smut mass which is produced in corn. Not all the smuts of cereals are caused by the same fungous plant. That is, the smut of corn is not the same smut that attacks wheat, nor is the smut of wheat the same as the smut of oats. Each smut is a separate disease and has its own life story, although two or more smuts may have a similar life history. For instance, the oat smut and the stinking smut of wheat are similar in their life stories, but oat smut cannot be transferred to wheat, neither can wheat smut be transferred to oats. In order to illustrate the different life histories

and methods of combating, the smuts of cereals may be divided into three groups.

1. *Stinking Smut of Wheat, Oat Smut, and Covered Smut of Barley.* These three smuts, although distinct, have a similar life story, which was briefly described above. The smut spores cling to the grain over winter, are planted with the seed, and grow when the grain grows. The threads which are thus produced by the spore get into the grain plant and grow up with this plant until heading-out time. The threads then fill the kernels and convert them into a black, smutty mass. As pointed out above, the treatment of the seed is clearly the most efficient method for treating this class of diseases. If, for instance, one puts the seed in hot water at about 130° F. (for details of treatment see various State Experiment Station and United States Agricultural Department bulletins) for ten to fifteen minutes, the smut spores on the outside of the grain are killed, while the grain itself is not injured. Careful washing of the seed will also remove a good many of the spores. Other methods are useful in connection with this group.

FIG. 139. — Oat Smut.

(After G. P. Clinton.)

For instance, a 40 per cent solution of formaldehyde (which can be obtained in any drug store) when mixed with water in the proportion of one pint to about forty gallons can also be used. This solution poisons the spores and kills them, while it does not affect the grain even if the grain is allowed to stay in it for two hours.

There is no excuse for any farmer having any of the three smuts just mentioned, as he can kill them at the cost of a very few cents an acre of grain.

FIG. 140. — Stinking Smut of Wheat.

1, a head of wheat with smutted grains (smutted grains are colored black); 2, small portion of a head showing smutted grains which are fissured, and show the black spore mass within; 3, isolated grains which are smutted and have fissured walls. One grain is sectioned; 4, smut spores germinated and producing at the end of the germ tube long, needle-like spores, which sometimes fuse together in pairs by cross threads as shown on the left; 5, the thread spores, shown in 4, in germination sometimes again producing secondary spores; 6, smut spores germinating to long infection threads without first forming spores. 4–6, highly magnified. (After Tubeuf.)

2. *Corn smut* forms large, boil-like structures on the leaves, ears, tassels, or any other part of the corn. These boil-like structures develop into masses of powdery material; that is, the spores of the fungous plant. The

spore masses usually find their way to the soil when they are cut down, or else get into the manure pile. The spores may grow in the manure pile or live over the winter in the soil and in the following early summer or spring the threads from the smut spores will again pinch off little spores that are carried by the wind on to the corn plant. Here these spores send out threads which find their way into the corn plant, where they develop rapidly and form another boil. In short, then, the spores live over the winter in the manure pile or soil, and the corn plants are infected in the early summer from these spores that live over. It should be noted that the spores do not live over on the seed; hence, there is no necessity or use in treating the seed. The only method now known of reducing corn smut is to prevent if possible the smut masses from getting either into the soil or the manure pile, and to handle the manure pile

FIG. 141. — Corn Smut (*Ustilago maydis*), on an Ear of Corn.

A few of the kernels near the butt have not been smutted. All the others have been attacked and have increased enormously in size. The enlarged kernels are filled with the smut powder. (Minn. Plant Dis.)

wisely; that is, use well-rotted manure, as the spores may have died out in such manure.

3. *The Loose Smuts of Wheat and Barley.* These smuts cannot be described in detail here, but are men-

tioned briefly merely to call attention to the diversity
of life stories in the smuts. Ordinary seed treatment
as described above will not prevent the loose smut of
either wheat or barley. The reason for this is as follows:
These smuts are early smuts; that is, the smut mass is
produced early in the summer. The spores are blown
about by the wind, and some of them are blown into
the flowers of healthy wheat plants, where they im-
mediately begin to grow. The threads then get into
the seed before the latter ripens, so that at harvest time,
in the case of loose smut of wheat and barley, we have
the fungous threads already inside of the seed buried
to some depth in the germ. The difference between
this smut and the stinking smut of wheat and covered
smut of barley, where the spores are on the outside of
the seed, can be seen. It should be clear that where
the fungous disease is already inside of the seed, the
ordinary washing or poisoning of the outside of the
grain will not be effective, and this has proved to
be the case. The ordinary seed treatment is there-
fore useless. The only effective method known at
present is to soak the grain for some hours and then
to treat it severely with hot water, which apparently
kills the fungi inside of the grain and does not kill all
the grain, although some of it is not strong enough to
survive.

It will be seen from this description of the smuts that
if a farmer has smut in his barley, in order to handle
it intelligently he must know whether it is covered
smut or loose smut, the treatments in the two cases
being different, because the life stories are different.

The Blight of Potatoes — Spraying. — Potato blight
is an exceedingly serious disease, especially in wet

years. Losses of ten millions of dollars in one year in the eastern states of the United States have been known.

Where the conditions are favorable for the disease, it travels with great rapidity and may destroy a whole field completely in twenty-four to forty-eight hours. This being another type of plant disease, it is combated by altogether different means from those used against smuts of cereals. It can be almost entirely prevented by foresight and the application of methods based on the life story of the fungus.

The following life history will illustrate: The disease may live through the winter in the potato tubers, possibly also in the vines. Along in July the threads

FIG. 142. — Early Blight of Potato.

The life story is somewhat different from later blight, but the treatment is similar.

work their way into the leaves and here grow very rapidly, killing the tissues of the potato plant. The threads increase in number and soon send branches out through the pores in the surface of the leaf, and these special threads pinch off spores. From this exposed position on the surface of the leaf the spores are blown by the wind and may fall on other leaves. Potato blight can spread rapidly only in damp or wet weather, because these spores falling on the

leaves do not produce a thread immediately, but break up into other little spores which swim about in the water.
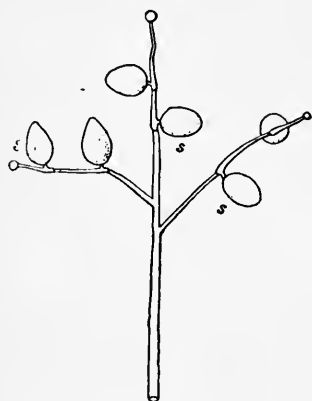
FIG. 143. — Potato Blight (*Phytophthora infestans*, one of the downy mildews), thread with spore-like swimming-spore cases. (After DeBary.)

These little swimming spores swim around in the drops of rain or mist for a time, but finally come to rest. Then they send out little threads which penetrate the leaves and a new infection is started. This scattering of spores from leaf to leaf and the growth of a new mycelium in each leaf may be very rapid and, as mentioned above, may destroy a whole field in a very short time. Some measures for combating this disease are already apparent. Diseased tubers for planting should always be discarded. The most effective method, however, for fighting this disease is by spraying on the plant a solution which is particularly poisonous to the fungus. This solution is known as Bordeaux mixture and is prepared by mixing a solution of blue vitriol with limewater. (For detailed directions see Experiment Station bulletins.) This Bordeaux mixture is sprayed on in as fine a spray as possible, the formation of large drops being avoided. The spraying is done at regular intervals, commencing early in July before any disease appears on the potatoes. After the plants are thoroughly sprayed with the mixture, an examination of the leaves shows very fine spots of the Bordeaux mixture all over the leaf. If now some spores of

the blight are blown on to the leaf, they may fall between these spots or into them. The spores, it will be remembered, do not grow unless water is present, when they break up into swimming spores. When water is present, the Bordeaux mixture spots, which may have dried out in dry weather, again diffuse through the drop and the little swimming spores find themselves in a little lake of poisoned water. The finer the spray, the more numerous are these little lakes and the less numerous are the safe places between them. It will also be seen from this that spraying is a preventive measure, not a cure. It would do no good to spray a plant after it already has the blight, because the blight in such a plant is inside of the leaf. Moreover, when heavy rains wash

FIG. 144. — A Barrel Pump for Spraying Plants.

off the Bordeaux mixture, it must again be applied in order to keep the plants covered by the mixture. When the Bordeaux is properly applied, it will not injure the foliage.

There are large numbers of plant diseases which attack the leaves and above-ground portions of plants which can be prevented by spraying. The most commonly used material for spraying is the Bordeaux mixture, though other substances are sometimes used. The life stories of the diseases which can be prevented by spraying are not always similar to that of the blight

of potato. The general principles are, however, quite
similar; namely, that the spores which scatter the disease
fall on the leaves or other above-ground parts of the
plants, where they may cause infection; then they
start to grow and are killed if the spray material is
already on the leaf.

Damping-off of Seedlings — Soil Treatment. — The dis-
ease known as damping-off is very common all over

the world. It affects
many kinds of plants
under a great many dif-
ferent conditions. It is
most common and se-
rious in greenhouses and
nurseries. Pansies and
many other greenhouse
plants are very com-
monly severely injured.
In nurseries seedlings of
conifers and other plants
are seriously affected.
The disease strikes the
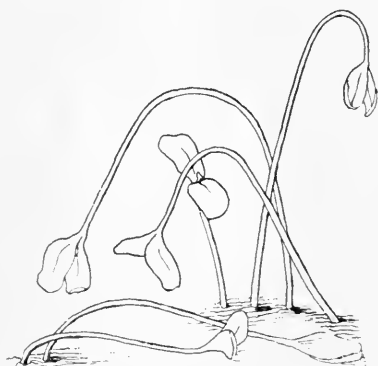
FIG. 145. — Flax Wilt. Wilted Seedlings.
(After Bolley.)

seedlings just after they push up above the ground
and while they are still very tender. It blackens the
stem just at the surface of the soil, killing it and caus-
ing the seedling to tumble over and finally to wilt and
die.

This disease is caused by a fungous plant which exists
for the most part in the soil where the spores live over
the winter. There are, however, a number of fungi
which have been known to cause this disease, so that
damping-off in any particular case may be due to one
or more of these fungi. They do not all have the same

life history, but they have this feature in common, that they pass most of their life in the soil and usually are able to live saprophytically, that is, on the dead material of certain other plants. They also all possess the power of becoming parasites by attacking the seedling plants. Another feature which these fungi have in common is that they thrive best under moist conditions. Low situations, therefore, water-logged soil, poor drainage, or bad ventilation, as in a greenhouse, will all contribute to the spread of this disease.

The life story of one of the most common and best known of these fungi may be given as an illustration of how they live. This fungus is commonly known as damping-off fungus (*Pythium debaryanum*). It produces comparatively large threads, which grow in the soil and under proper conditions give rise to little cases which finally break and let out tiny spores that are provided with whiplike lashes. These lashes enable the spores to swim around in the water. The spread of this fungus is therefore made easy by an abundance of water in the soil or at the surface of the ground. These swimming spores finally come to rest, pull in their lashes and grow out into threads which lengthen and branch in the usual way and finally build up a mass of threads, that is, a mycelium. If the soil dries up or other conditions come about which are unfavorable to the growth of the fungus, the threads may form another kind of spore which may be called a resting spore, or winter spore. This spore is quite large and has a very thick wall, so that its contents are well protected. It can endure a great deal of drying out and cold, and will, when favorable conditions return, again break up into swimming spores. These swimming spores grow as

those described above and again a mycelium is built up. It will thus be seen that this fungus is well adapted to living in the soil on dead material and young seedlings. It can grow rapidly where a great deal of moisture is provided and can spread rapidly by means of its spores. It is also so equipped that it can resist dry or other unfavorable conditions.

From what has been said of the life history of this fungus the means of fighting the disease can easily be surmised. Drainage of the soil and ventilation in the case of greenhouses so that water will not collect at the surface of the soil can both be recommended. The sanding of seed beds also helps. This is commonly practiced because it keeps the surface of the soil dry, for it is close to the surface that the disease strikes the seedlings. Since the disease occurs mostly in seed beds of one sort or another, too frequent watering should be avoided. In some cases the soil becomes so badly infected with the disease spores that it is impossible to grow seedlings. In such cases it is sometimes necessary to sterilize the soil for these seed beds. This is done by heating it, which kills off all the spores in the soil. Large seed beds, such as those grown for evergreen trees, are sometimes treated with solutions of sulphuric acid, by which the soil is partially sterilized. This has been found to give good results in certain cases. In general, therefore, the treatment of this disease lies in the proper treatment and handling of the soil.

What has been said about damping-off and its relation to soil treatment applies, at least in part, to a large number of plant diseases which inhabit the soil and which may attack mature plants as well as young.

For instance, flax wilt is a disease of this sort, living almost entirely in the soil. It is obviously impossible to sterilize the soil, but good drainage is useful. Since the fungus may accumulate in the soil, the chief remedy for such a disease as flax wilt lies in rotation of crops, so that the fungus in the soil may be allowed to die off between the crops of flax. It has been found necessary where flax has been raised for a long number of years to rotate the crop so that the flax shall not be put in the soil more than once in five to seven years. The reason for this is readily inferred from the life story of the disease. In the case of flax wilt other methods of treatment, namely, seed treatment with formaldehyde and resistant varieties, are also necessary.

Potato Scab. — Potato scab is a disease of potato tubers causing scabby patches on the skin. It lives and accumulates in the soil in a manner somewhat similar to flax wilt. Rotation of crops may therefore be necessary in severe attacks of the disease. Ordinarily, however, the disease can be prevented by treating the seed potato with a corrosive sublimate solution or a solution of formaldehyde, thus destroying the fungous parasite on the skin of the potato.

Rusts of Cereals — Resistant Varieties. — The rusts of cereals are among the best known of the diseases of agricultural plants. These rusts have been known since the time of the Romans and undoubtedly caused losses in times even earlier. Rust epidemics in recent years have been common in almost every country on the globe where cereals are raised in quantity. As with the smuts, so here, the disease which is to the farmer known as rust of wheat, oats, barley, and so forth is really a collection of diseases. There are in other words, two

kinds of distinct rusts of wheat, and two of each of the other common small grains. The life stories of these various rusts are, however, somewhat similar. At least they are not so different as to demand such difference in treatment as is found in the case of the smuts.

The life story of one of these, namely, the stem rust of wheat, commonly called black rust, may be cited by way of example. Just before the wheat plants in the field begin to head out there may be found on the stems and on the lower parts of the leaves brownish red powdery masses which are formed in streaks. These are the so-called summer spores of the stem rust. The spores are blown off by the wind and new ones formed from the same pustule, or streak. The wind-blown spores fall on other wheat plants, and if a drop of dew collects around them or a drizzling rain provides some water, they start to grow by sending out a fungous thread. This thread digs its way into the leaf or stem, commences to branch, and forms a tangle of threads, and this tangle soon breaks open the outer covering of the leaf and again forms red, or summer, spores. This spore, therefore, is particularly

FIG. 146. — Wheat Rust (*Puccinia graminis*).

Stems of wheat showing opened and unopened black clusters of winter spores. This is commonly known as "black rust" or "stem rust." Slightly magnified.

adapted to spreading the disease through the wheat field in the summer time.

As the wheat plants begin to ripen just before harvest, the fungous threads which have produced the summer spores now begin to produce spores of a darker color, which are provided with thick walls and which in the pustule look black. These are the winter spores and are commonly called the black rust. They are really only the winter stage of the stem rust. These winter spores are not blown about by the wind, but remain on the straw over winter.

The summer stage, commonly called red rust, and the winter stage cause a great deal of damage to the wheat, first by breaking open the epidermis, or outer covering, and allowing the water to evaporate from the stem. In the second place, where the wheat plant is badly infected with the disease, a great deal of nutrition is taken by the parasite. This becomes especially dangerous in the stem rust of wheat when the rust covers the stem just under the head, as is the case in an ordinary epidemic of rust.

If now we follow the life story through the winter stage, we find that the winter spores which remain on the wheat straw will not germinate until the following springtime. They then send out a little thread from which about four tiny spores are cut off. These spores are blown by the wind. If they fall on the leaves of a barberry plant (which is an ornamental, thorny shrub very commonly raised and introduced in most parts of the United States for hedges and other ornamental purposes), they will grow by sending out another thread and penetrating into the leaf of the barberry, where a mycelium is built up. If they do not

fall on the leaves of a barberry, they perish and are wasted.

The mycelium in the leaf of the barberry soon produces another kind of spore which may be called the
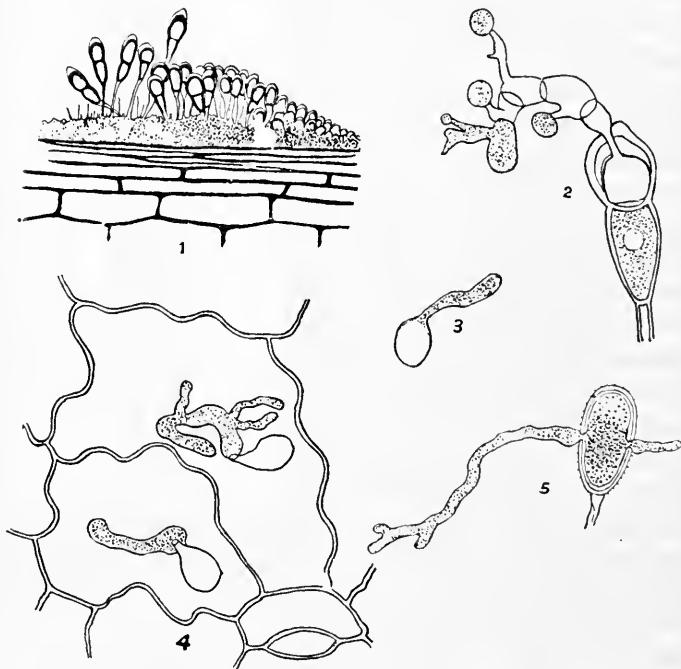
FIG. 147. — Spores of Wheat Rust.

, a cluster of winter spores of wheat rust (*Puccinia graminis*) on wheat plant; 2, a winter spore germinating to a thread of four cells (promycelium-basidium), each of which bears a small spore (sporidium) on a stalk. The winter spore germinates in the spring while still in the straw or on the ground. The sporidia are blown by the wind to another plant, and there germinate, as seen in 3 and 4 4, shows the germination of a sporidium on a barberry leaf; here infection will soon take place; 5, a germinating summer spore of wheat rust, showing germ tubes which on a wheat plant can cause infection. All magnified. 1–5, after Ward.

spring spore, produced in May or June in this country. The spring spores are produced in chains and look very

much like the summer spores. They are formed in little cups, which are known as cluster cups, and are blown off the barberry plants by the wind. These spring spores, or cluster cup spores, will not infect another barberry plant, but will be wasted unless they fall on a wheat plant. Here they send out the usual thread and infect the wheat leaf or stem, and build up a mycelium inside of the wheat leaf, which now produces the summer spore with which we started.

The life story, therefore, is seen to be quite complex. Summer spores are produced on the wheat plant in midsummer and up to harvest time. The same mycelium will then produce the black stage or winter spores. These live over on the straw of wheat until spring, when they grow, and by means of small spores which are blown by the wind, cause the infection of barberry plants, and on these barberry plants the spring spores are produced. The spring spores are then blown to the wheat plants and again cause the summer spores.

As has been before mentioned, the life stories of the different rusts of cereals are not all similar. The wheat stem rust, as described, lives on two plants, the wheat plant and the barberry plant. Some rusts, as, for instance, one of the oat rusts, lives on the oats and on the buckthorn.

Another possibility of the life history needs to be mentioned. The rusts of cereals are able also to infect certain wild grasses which live through the winter. The summer stage of the rust on these grasses is sometimes formed late in the fall and may live over the winter under the snow so that the summer spores on these grasses may appear early in the spring and start another infection, when they are possibly carried back

again to the wheat plant. This method of living over the winter will be seen to be independent of any barberry plants. In short, the stem rust of wheat may live over the winter in the summer stage and also in the winter stage. The summer stage that lives over does not need a barberry plant, while the winter stage does. The wintering over of the summer stage is comparatively easy in our southern states, as, for instance, Texas, where the winter is not so severe, but it is also known to occur as far north as Minnesota and North Dakota.

In view of what has been said of their life history, the possibilities and difficulties of combating rusts may now be mentioned. Seed treatment, such as is commonly used for smut, has apparently no effect on the rust; neither will the treatment of the soil assist in any way, since the spores do not live over in the soil. Even the burning of the straw with the black or winter stage on it has not given any beneficial results, since the summer stage can live over the winter on the wild grasses or the summer spores may be blown up from the south, where they can easily live over the winter on winter wheats or wild grasses. Of the most common methods for treating diseases which have been mentioned above, spraying is the only one left to consider. The spraying of the fields of wheat is apparently an impracticable remedy. Moreover, the spraying of Bordeaux has never been found to give very beneficial results. Even if it were possible to prevent the disease by spraying, it seems probable, from the nature of the crop and the difficulty of covering such large areas as would be necessary to cover, that the spraying of rust would be impracticable. It has been necessary, therefore,

to discover other methods for combating the rusts of cereals.

It was formerly thought that rust spreads most easily in muggy or foggy warm weather, following sunshiny weather. It has been recently found that this is not the case, but that it spreads best in cold cloudy weather during the period between heading out of the grain and harvest time. The reason for this is that the rust spores germinate best and the mycelium also grows best at a low summer temperature. Cool weather also brings abundant dew which furnishes water drops for the spores to grow in. Water may also be furnished by rain or fog, but heavy rains tend to wash off large numbers of spores. Hot weather is unfavorable to the growth of the rust, but after the rust has gained a foothold it may increase the rust damage by drying up the plants more rapidly on account of the wounds in the skin caused by the rust. Since man has no control over the weather conditions, control of the rust is very difficult. From these considerations it is seen that the selection of a proper locality for the cereal is important, since wheat in a low situation is apt to have more moisture and colder night temperature than wheat in high situations. Good drainage is also somewhat important. In irrigated countries too much water must not be used, but it is a noticeable fact that rust seldom causes damage in irrigated districts. Another feature of good farming which would assist in keeping the rust in check is the rotation of crops, since it would tend to the production of less of one kind of cereal and thus make the travel of the disease from one locality to another less likely. The growing of wheat or any other single cereal crop all over a certain district or

state, such as was and is commonly practiced in the prairie states of the Mississippi Valley, furnishes an excellent method for spreading the rust. All the combative measures so far mentioned are merely in the nature of mild precautions. They will not always prevent the rust and in the case of an epidemic will have no effect at all in most cases. They should not, however, be neglected, since they constitute methods of good farming regardless of the rust question.

The most hopeful remedy for rust has yet, however, to be mentioned, and this is the selection of varieties. It is found where varieties of wheat differ in the time of maturing one or even two weeks, that the early variety more often escapes the rust than the late variety. That is, the rust epidemic may come along just too late to catch the early variety. Sometimes an early variety may be attacked where a late variety is not, but more often the early variety escapes. It can usually be recommended, therefore, that early varieties be planted. It is well known that the stem rust of wheat is not usually so severe in the winter wheat districts as it is in the spring wheat regions, and in the latter regions where wheat can be grown the winter wheat frequently escapes the rust on account of its earliness, while the spring wheat may be attacked.

Finally, rust may be prevented to a large extent by the selection of varieties which are known as resistant varieties. In wheats, as in a great many other plants, different varieties give different reactions against a certain disease. Some varieties may be very susceptible to a disease, while others may resist the disease: just as in human beings certain people are predisposed toward certain diseases, while others, although exposed

to infection, may escape. Varieties of wheat resistant to rust are known. The group of wheats known as durum, sometimes called macaroni wheats, contains a great many varieties which are actually resistant to rust. Some of the durum wheats are not at all resistant, but a large number of the varieties have demonstrated their resistant powers in experimental fields as well as in actual epidemics. Unfortunately these durum wheats are not adapted to all the localities where other wheats can be grown so that they cannot be recommended in place of the spring and winter wheats in every case. In the raising of any crop all the factors tending to the production of the most profitable yield must be considered, and rust is only one of the factors. Durum wheats do not command so high a price as spring and winter wheats and the farmer rightly takes this into consideration. The fact remains, however, that many durum wheats can be grown which will resist severe epidemics of rust. It remains for the farmer to decide whether the rust is a sufficiently important factor to warrant the growing of this sort of wheat. Many experiment stations, as well as the United States Department of Agriculture, are now attempting by plant-breeding methods to develop varieties of spring and winter wheats which have resistant powers against rust and which still retain the other desirable characteristics of these wheats. The history of plant breeding has already shown that it is possible in some cases even in a very short time to develop by selection or crossing varieties which are specifically resistant to certain diseases, and this is hoped for in the case of rust of cereals.

CHAPTER VI

INSECTS AND OTHER SMALL ANIMALS

Destructive and Valuable. — The enormous losses suffered through the depredations of insects and other small animals on the farms of America reach such large amounts that the knowledge of the life history of these small animals and how to control them becomes of great importance in crop production and comfortable living. The money losses of such depredations are variously estimated from $700,000,000 to $1,000,000,000 annually.

On the other hand, some insects prove of great benefit to mankind by holding in check the harmful kinds, while still others produce a product of great value. The Hessian fly is responsible for a loss of $50,000,000 annually, while bees produce a product valued at $10,000,000 annually.

WORMS (*Annulata*)

This branch of the animal kingdom is familiar to every one. A tubular body made up of a number of rings, or segments, having a digestive system consisting of a tube running through the body, a distinct nervous and circulatory system, and reproducing by means of eggs, include the chief characteristics of worms.

The common earthworm, or angleworm, is the most important member of this branch. Darwin made a

special study of the earthworm, making prominent its great importance and benefit to agriculture. He estimated that in some parts of England this little animal, in boring, brings to the surface ten tons of subsoil to the acre. It bores its hole in the ground by passing the earth through its body. This hole may be six to eight feet in depth.

The angleworm feeds on organic matter in the earth, and sometimes draws into its hole small bits of leaves which it uses as food. During the day it remains in its hole unless forced out by the filling of its hole with water, as during a heavy rainstorm, but at night it comes to the surface to feed. During the winter it hibernates below the frost line.

It is difficult to estimate the value to agriculture performed by these little creatures. The large amount of subsoil worked over by them and deposited at the entrances to their holes in little pellets of earth, called castings, is one means of constantly renewing the soil. The holes also admit air and water, both beneficial to the subsoil; and the vegetable matter drawn into their holes increases the humus in the soil.

FIG. 148. — Earthworm.

a, the worm itself; *b*, a small part magnified to show bristles pointing backward. These aid the worm in moving forward. *c*, egg of worm; *d*, young worm coming out of the egg. (Burnett.)

Note. — Tapeworms, which infest the intestines of animals, and trichinæ, small worms found in the lean part of pork, are parasitic worms not belonging to the same division as the Annulata.

The trichinæ, small microscopic animals, are the most important. Hogs become infected by eating some animal, possibly a rat, that has the trichinæ in its muscles. When taken into the intestines of the hog, they increase to great numbers, and then work their way into the flesh, where they become surrounded by a cyst. Man may, in turn, become infected by eating raw or partly cooked pork. The only way to avoid this danger is always to have pork thoroughly cooked before it is eaten.

Insects (*Insecta*)

Characteristics. — Many people improperly include in this class all small animals, speaking of the coral insect and also spiders as belonging to this class. There are more different species of insects than of any other class in the animal kingdom, but there should be included under this term only such as have certain definite characteristics. In general it may be said that insects have their bodies divided into three distinct parts: the head, the thorax, and the abdomen. The head, which is the first segment, is furnished with a pair of jointed organs of variable length, called *antennæ;* the thorax has three segments, to each of which is attached a pair of jointed legs, six in all; the abdomen has usually nine segments. Many insects have two pairs of wings, some have only one pair, while still others have none.

Metamorphosis. — All insects go through certain changes of form from the egg to the fully developed insect. Such a change is called a metamorphosis. A complete metamorphosis involves four distinct states: first, the egg; second, the larva, which is the caterpillar, grub, or maggot stage; third, the pupa, or chrysalis stage, in which the larva is inclosed in a cell of silken material, or a protecting case, or often is naked;

fourth, the imago stage, which is the fully developed insect.

Some insects pass through all the stages mentioned, while others omit the pupal stage, the one corresponding to the larva then being called a nymph; and still others both the larval and the pupal stages; in which cases they are said to pass through *incomplete* metamorphosis.

Insects are classified, according to peculiarities of the wings and other characteristics, into orders.

Locusts (*Orthoptera*, straight-winged). — This order has its fore wings straight; its hind wings are gauzy and folded in fanlike plaits. Its members have well-developed jaws and powerful legs. The metamorphosis is incomplete, the larval and the pupal stages being wanting. To this order belong locusts, grasshoppers, crickets, katydids, and cockroaches. The seventeen-year locust is not a true locust and does not belong here.

The Rocky Mountain or Migratory Locusts. Since the time of Pharaoh locusts have been feared by mankind. When the crops are ripening, locusts sometimes appear in swarms, sparing nothing that is green, often destroying the entire crops of sections over which they pass. In the seasons of 1874–1876 the losses sustained from this pest were over $50,000,000.

The locust appears in small numbers every summer, but its natural enemies and the unfavorable conditions for the development of the insect from the egg keep it from being a great pest. It is probable also that the cultivation of large areas of the western country, and fall plowing, will destroy the eggs so that it may never again pass over large areas of country, causing complete devastation.

The female forms a little hole in the earth with her ovipositor and then deposits her eggs at the bottom.
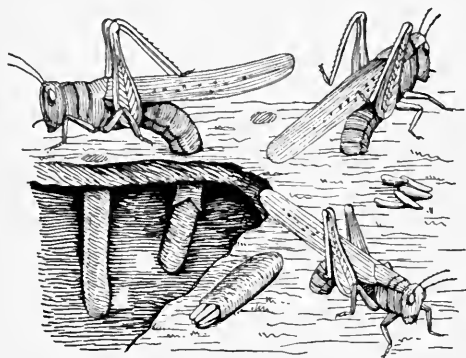
FIG. 149. — Grasshoppers laying Eggs.

Here they remain till spring, when they hatch out into young locusts. The young molt, or change their coats, two or three times before they reach the adult stage with fully developed wings.

If locusts are marching across a country, poison baits, hopperdozers, spraying, and other measures give only temporary relief. For the native grasshopper fall plowing is the best preventive measure, as it destroys many eggs by throwing them to the surface, where they may be eaten by the birds or destroyed by exposure.

Cockroaches. These insects seek some dark crack or crevice in the daytime and come out to feed at night. They are most numerous in damp basements and about water pipes and bathrooms. Their eggs are laid in a capsule carried about by the female until she finds a convenient place for deposit. Cockroaches are difficult to get rid of when they infest a dwelling, but a liberal sprinkling of powdered borax in cracks and crevices where they abide will usually drive them away.

Dragon Flies (*Odonata*). — This order has long, lace-like, gauzy wings and well-developed jaws. Their metamorphosis is incomplete.

The dragon fly, with its long slender body, large eyes, and brilliant wings, may be seen darting about in the summer. It is called the Devil's darning needle and also the mosquito hawk.

The eggs are deposited on the water or on some stem growing in the water. The young when hatched

FIG. 150. — Dragon Fly.

feed on the larvæ of other insects found in the water. In the imago, or fully developed stage, they catch their prey and feed on it in the air. This insect destroys numberless mosquitoes, both in the water and out.

Beetles (*Coleoptera*, sheath-winged). — There are probably one hundred thousand different species of beetles. Their mouth parts are developed for biting; the fore wing is horny and the hind wing is gauzy and folded under the fore wing when not in use. Beetles go through a complete metamorphosis.

It is, of course, impossible to name here all the beetles, but a few of the most common included in this order are : June bugs, ladybirds, potato bugs, burying beetles, blister beetles, weevils, fireflies, tumble bugs, and curculios.

Potato Bugs (*Colorado potato beetles*).   This insect is
improperly called a bug.   It is a beetle, and one of the
most destructive of its kind.   It originated in the
Rocky Mountains, and at first lived on a kind of wild
potato plant.   As soon as cultivated potatoes were
introduced, the beetle
devoured the leaves of
the   cultivated   vari-
ety   and   soon   spread
throughout the coun-
try.

The beetle lays from
five   hundred   to   one
thousand eggs in a sea-
son, usually in clusters
on the under side of the
leaf of the potato.   As
soon as these hatch, the
young larvæ commence

FIG. 151. — Potato Beetles, Larva, and Eggs.

their feast on the leaves, where they keep on eating and
growing for about two weeks; then they bury them-
selves in the ground to pass the pupal stage.   After
ten days they come out as beetles, with the distinctive
yellow-striped wings.   In the imago stage as well as in
the larval the beetle eats the potato vines, but they
are especially destructive during the larval stage.

The best means of killing potato beetles is with a
spray of some arsenical solution.   Paris green in water,
about one pound to fifty gallons, is probably the most
common means of destroying the beetle.   Some prefer
to mix Paris green with dust, or preferably flour (one
pound of Paris green in four pounds of flour), and shake
it over the vines when they are wet with dew,

The cheapest and safest poison to use is arsenate of lead. This is applied the same as Paris green, but it will not burn the leaves as Paris green does if used too strong. The arsenical poison may be mixed with Bordeaux mixture, and the combination used as a spray will prevent wilt and kill the potato beetles. (See page 61 for method of making Bordeaux mixture.)

The Lady Bug (*Ladybird*). This beetle is one of the useful kind. It feeds upon the eggs, larva, and

FIG. 152. — Ladybird Beetles, or Lady Bugs.

The straight lines represent the average natural length. These beetles are very destructive to plant lice.

imago of other destructive insects. One species devours the eggs of the potato beetle.

The Buffalo Moth (*buffalo bug, buffalo beetle*). This destructive insect is not a bug or a moth, but a beetle. It attacks carpets laid on the floor, and improperly protected garments or furs. It acts very much like the clothes moth.

To get rid of the buffalo beetle, thoroughly wash the floors with soapsuds, then drench them with benzine or kerosene; beat the carpets and rugs thoroughly before laying them on the floor. House cleaning of this kind should be repeated twice each year.

Note. — Weevils are beetles that often attack peas, beans, and various other seeds in storage; if these can be placed in closed vessels with a small quantity of carbon disulphide (see page 58) and allowed to remain for a few hours, the weevils will be destroyed. All flames should be kept away from this substance as it is dangerously explosive.

Weevils are also found in flour and often infest flour mills. The only practical method of killing them in flour mills is to use hydrocyanic acid gas. This gas is fatal to all animal life, and should be used only with the utmost caution and by those who understand the proper method of using it. The mill or room to be fumigated is closed tightly and arrangements made for properly ventilating it without entering it after the fumigation is complete. One ounce of cyanide of potash is used for each one hundred cubic feet to be fumigated. A four-gallon crock containing five pounds of sulphuric acid and seven and one half pounds of water should be left in the room. Just before leaving, three pounds of cyanide of potash done up in a paper package should be dropped into the crock. One should then leave the room quickly, closing the door. The fumigation should proceed for not less than twenty-four hours. Ventilate the room or building thoroughly before reëntering.

The Mexican Cotton Boll Weevil. This beetle from Mexico has spread over large portions of the cotton-growing sections of the south, doing great damage.
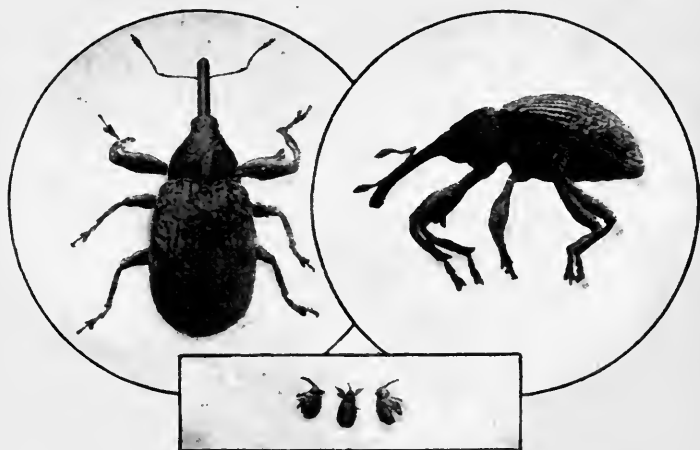
FIG. 153. — Mexican Cotton Boll Weevil.
Much enlarged, above; natural size, below. (Herrick.)

The young larvæ eat and destroy the tender inside parts of the cotton boll. The Department of Agriculture of the United States has a corps of expert entomologists at work trying to discover some practical means of destroying the pest.

Plum Curculio. This beetle with a hump on his back not only causes plums to drop before they are ripe and makes cherries wormy, but it does great damage to the apple crop. The female lays her egg under the skin of the fruit, and then makes a crescent-shaped cut in the skin around the point where the egg is deposited. This cut serves to loosen the skin so that the egg may not be crushed with the growing fruit pulp. Numerous sprayings with arsenate of lead or with Paris green in the early spring may poison the female before her eggs are laid. If the infested trees are jarred by a sharp blow from a padded club, in the early morning when the beetles are torpid, they may loosen their hold on the tree and fall to the ground. Sheets should be spread under the tree to collect the beetles, that they may be destroyed.
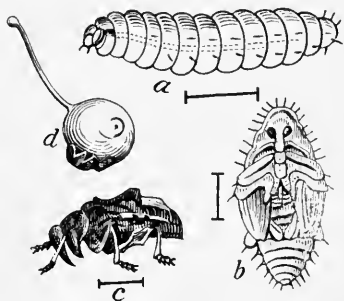
FIG. 154. — The Plum Curculio.

a, the larva; *b*, the pupa; *c*, the beetle; *d*, curculio, on young plum. The straight lines indicate the average natural length.

Bugs and Lice (*Hemiptera*, half-winged). — Many people call all insects bugs, but the term is properly confined to this order of insects. They are characterized by having the mouth parts transformed into a bill or beak that fits it for sucking juices from plants and

animals. Some have their wings thickened at the base, the outer portion being membranous. This gives the name *Hemiptera*. Still other members of this order have two regular wings, and others have no wings at all.

Many bugs emit a very disagreeable odor. Their metamorphosis is incomplete, there being no quiet pupa stage.

This order includes the cicada, or so-called " locust," also the seventeen-year locust that makes a sound that we are all familiar with in the hot dog days, hence it is often called the dog-day harvest fly; lice, infesting both plants and animals; scales; bedbugs; leaf hoppers; chinch bugs; squash bugs; skippers; and many others.

Plant Lice (*Aphides*). These may be found on all parts of plants, where they often do great damage by sucking the juices. They are usually more or less pear-shaped, green, white, or gray in color. They are held in check under ordinary conditions by their enemies. One of these, a parasitic, four-winged fly, lays its eggs under the skin of the insect, eventually eating out the insides, and another, the lady bug, devours great quantities of the lice. When their natural enemies are for any reason reduced in numbers, the aphides become a great pest. The green bug that did such great damage in the summer of 1906 was a plant louse that developed in numbers sufficient to destroy the small grain crop in some sections of the country. Nearly every plant has some species of plant louse infesting it. Some are on the leaves, some on the stem, and others make galls on the roots of the orchard trees and of grape vines. Plant lice may be

destroyed by spraying with a kerosene emulsion made according to the following formula :

> Hard soap, or soft soap, one pound
> Kerosene, two gallons
> Water, soft, one gallon

Dissolve the soap in boiling water; remove the kettle from the stove and add the kerosene while the water is still boiling hot; churn the mixture with a spray pump until it gets to be a soft, butterlike mass. For use this may be diluted with five to ten times the amount of water. Since the members of this order are not biting but sucking insects, it is useless to use poisons of any kind on the leaves.

Scales and Mealy Bugs. There are different kinds of scales that infest orchard and other trees, but the most destructive and widespread is the San José scale, so called because it first appeared at San José, Cal. This is a kind of plant louse that usually remains on one portion of the stem of the tree, and, in the case of the
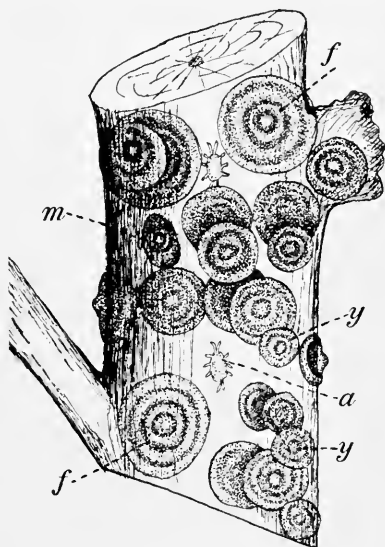
FIG. 155. — San José Scale Insect.

m, male scale; *f*, female scale; *y*, young scale; *a*, young insect. Enlarged.

female, does not move after it once settles down. It covers the stems with a whitish coating that might

be mistaken for whitewash or ashes, but on close examination with a magnifying glass, its true character is plainly seen. Orchards should be inspected carefully for this insect, and no trees should be planted that have any scales on them. The best remedy for the scale is to spray the trees in the winter with kerosene or use the lime-sulphur wash, which may be made according to the following formula:

> Quicklime, 20 pounds
> Sulphur, 15 pounds
> Water to make 50 gallons

Boil the lime and sulphur one to two hours with a small quantity of water, then dilute to 50 gallons with boiling water. Do not let the mixture become cold; spray dormant trees while the mixture is yet warm. Lime-sulphur mixture may now be obtained on the market in form ready to use by the addition of water.
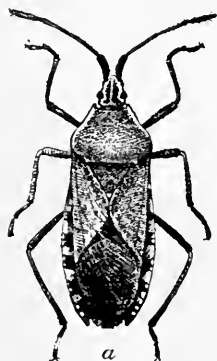
FIG. 156. — The Squash Bug.

a, mature female. (After Chittenden, Div. of Entomology, Dept. of Agriculture.)

Mealy bugs are present in greenhouses and hotbeds, and in the south on outdoor plants. They are a little soft-bodied, oval bug with a white fringe bordering the body. If the plant infested by these is hardy enough, a kerosene emulsion spray may be applied to get rid of them.

The Squash Bug. Whenever members of the cucumber family, such as squash, pumpkin, melon, and cucumber, are planted, this bug gives considerable trouble. The adult insect is dirty dark brown above

and mottled yellowish beneath. The young attack the leaves near the ground. They appear in June and successive broods hatch till October, when they hibernate. If the vines are collected in the fall and burned, large numbers may be killed. Land plaster soaked with kerosene or with turpentine will act as a repellent and drive them away from the vines.

The Chinch Bug. This bug does great damage annually to the wheat and the corn crop. The adult insect is less than one sixth of an inch in length. It is blackish in color with conspicuous snowy white wing covers. The young are red in color. They do not thrive in damp weather, but in dry weather the bugs that have hibernated in trash about the fields or in cracks of fences

FIG. 157. — Chinch Bugs.

come out and lay their eggs in large numbers in the mellow earth. They hatch out just as the grain is in a succulent condition and the young do great damage. No satisfactory remedy has been found for this pest, although many may be killed in furrows plowed across their line of march.

The Bedbug. This ill-smelling insect finds its way into houses and hotels of all classes. Persistent daily inspection, cleanliness, and a liberal application to all cracks and hiding places of a mixture of corrosive sublimate in alcohol and turpentine will keep this insect out of the home.

Flies (*Diptera*, two-winged). — This large order of common insects includes the common house flies,

fleas, and mosquitoes, although fleas are usually placed in an order by themselves. As is indicated by the name *Diptera*, they have but two wings (one pair). Some members of the order have no wings, or such small ones that they cannot be used for flight. The mouth parts are adapted for piercing or sucking. The metamorphosis is complete.

Common House Fly, the Typhoid Fly. — If this insect could be seen through a large magnifying glass at all

times, it would not be so common in the home and on the food that we eat, for the house fly is a disgusting-looking creature, its legs being covered with bristles which are usually covered with filth and often with disease germs. A few flies that live over the winter in the house or stable come out in the spring. The female lays her eggs in manure of any kind or in some decaying ani-
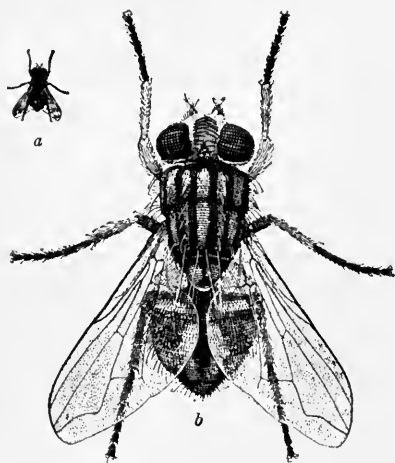
FIG. 158. — Typhoid Fly.
a, natural size; *b*, magnified.

mal or vegetable matter. She will also lay eggs on fresh meat or in open wounds. In twenty-four hours the eggs hatch and the maggot, or larval, stage is begun. This stage lasts about one week. The skin of the larva then hardens and turns brown, forming the coat for the pupa. It remains in the pupal stage for about one week and then emerges as a fly.

Much sickness is occasioned by the spread of disease germs through the fly. The large death loss from typhoid fever among the soldiers of the Spanish-American War was doubtless occasioned through the spread of the typhoid germs by flies. It is to be hoped that scientists may discover some means of ridding us of this pest, but till such time all should lessen the evil by excluding the fly from the home and by destroying their breeding places as far as possible. The house and all places where food is kept should be screened, and the flies excluded.

Note. — The Department of Agriculture has published several bulletins giving methods for exterminating the fly pest or of lessening its evil results. Many experiment stations have also issued special bulletins on this subject.

Other Varieties. There are many varieties of flies besides the common house fly, but they all have a similar life history. The *horsefly* punctures the skin before sucking. The *blow fly* of meat is a blackish fly with bluish abdomen, laying its eggs in meat. The *green bottle fly* incubates in manure in pastures. The *blue bottle fly* appears very early in spring and lays its eggs in meat. The *screw worm fly* resembles the green bottle fly, but lays its eggs in wounds or in the nostrils of cattle and even of human beings. The active maggots often cause sickness and sometimes death. The *horn fly* clusters at the base of the horns of cattle. Stock may be protected from flies by spraying with a mixture of three parts of fish oil with one part kerosene. Fish oil, cottonseed oil, and oil of tar may each be used for the same purpose. The application must be renewed at least every other day to be effective.

The Hessian Fly. This is one of the worst of insect pests of the wheat crop. It is supposed to have

FIG. 159. — Hessian Fly.

been brought to this country in the bedding of the Hessian soldiers. It is a slender fly with long legs, the body being about one sixth of an inch in length. It develops best in cool moist weather. The pupa of this fly is found inside the sheath and near the joint of the wheat stem. The pupa case is brown and resembles a flaxseed, on which account it is sometimes called the flaxseed stage. It is before this flaxseed stage that the damage is done by the larva, weakening the straw at the point that the flaxseed is placed. When the head of the wheat fills out and becomes too heavy for the weakened straw to sustain, a wind may cause whole fields infested by the Hessian fly to go down. Fall plowing will turn under the stubble and prevent a late brood from growing. In the south late planting of wheat has lessened the damage by giving no wheat stems for the larvæ to find when they are most desired.

The Mosquito. This member of the order is not only exceedingly troublesome, but it has been found to be the means of conveying yellow fever and malaria. Its mouth parts are shaped into a long bill. This consists of a set of piercing instruments, by means of which the female punctures the skin and sucks the blood of her victim. The male mosquito is harmless. The

life history of the mosquito should be understood in
order to combat the insect effectively. A mass of
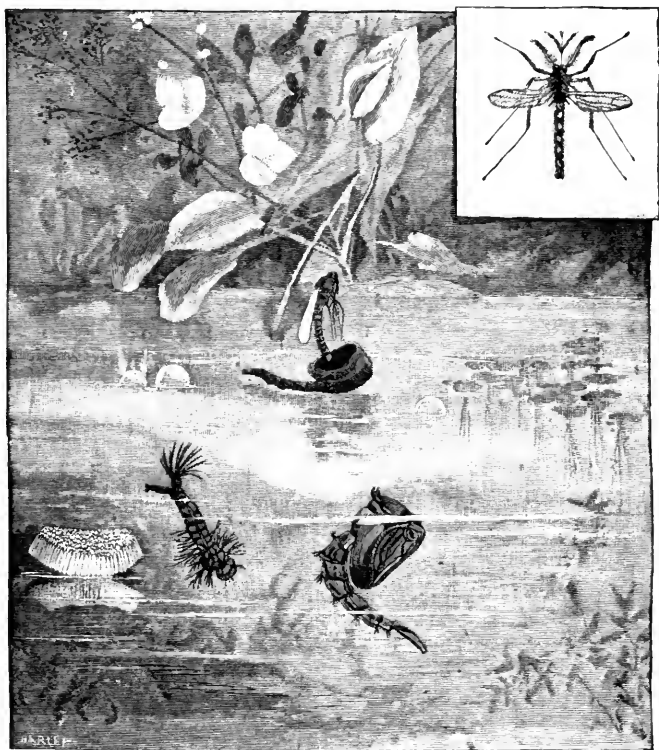
FIG. 160. — Metamorphosis of the Mosquito.
Eggs, larva, later stage on the raft, and adult. (Burnett.)

eggs somewhat boat-shaped is laid in the water. In
a few days they hatch into larvæ, called wigglers.
The wiggler breathes by means of a tube which at
intervals is thrust up into the air through the sur-
face of the water. After changing the skin two or

three times, it changes into the pupal stage. This is characterized by having two tubular, leaflike appendages extending from the thorax, which it thrusts above the surface of the water to get a supply of air. In a few more days its pupal skin bursts and the mosquito emerges, using the pupal skin as a kind of raft on which to float till its wings are dry. Rough water or flowing water upsets the raft, and the mosquito is drowned. The mosquito has many natural enemies. Fish eat large numbers of the wigglers. The dragon fly eats them as larvæ and in the imago form. A thin film of kerosene or crude petroleum on water will kill the wigglers when they attempt to get air. This is one of the methods used to destroy them in swamps and small lakes. A small amount of water, such as may be contained in a discarded fruit can, may be the breeding place of hundreds of mosquitoes. Rain barrels should be kept covered and low places near the home should be drained if we would decrease this pest.

Fleas. Fleas cannot fly, but they have very strong legs that enable them to jump great distances. The eggs of the flea are laid in the hair or fur of a dog, cat, or other animal, or in their bedding. If on the hair, they drop on the ground and in a few days are hatched. The larva lives for two weeks, and then enters the pupal stage, which lasts from ten days to two weeks.

If they infest the house, a liberal application of Persian insect powder on carpets and in any other places infested by them will usually kill them. Dogs and cats should be washed frequently with strong soapsuds, or with one of the coal tar dips.

The Botfly. — This fly lays its eggs on the hair of horses, usually on the front legs. If then a horse

licks the hair where the eggs are fastened, they hatch and are taken into the mouth of the horse. They soon find their way to the stomach, where the larvæ often collect in large numbers, fastening themselves to the walls of the stomach. They are not usually dangerous. They may be prevented by keeping the horse well groomed.

Ox warbles are a botfly that infest cattle. The eggs are fastened to the hair as with the ordinary botfly and reach the gullet of the animal in the same way. From the esophagus the larva works its way through the tissues till it comes to the hide. Here it makes a small hole for breathing and for escape. It remains here and causes a tumor to form under the skin. These tumors are called warbles. In the early spring the larva comes out, falls to the ground, and, after digging into the soil a few inches, changes to the pupal stage. After about a month it becomes a fly. The larva causes great damage to hides by puncturing them, millions of dollars being lost annually on this account. No satisfactory remedy has been found for the warbles.

Butterflies and Moths (*Lepidoptera*, scaly-winged).— This order is characterized by having the wings covered with feathery, overlapping scales. The mouth parts are formed into a tubular tongue which, when not in use, is coiled under the head. They pass through a complete metamorphosis.

Butterflies are distinguished from moths in a number of ways. The most apparent differences are the following: (*a*) The moths are night fliers as a rule, while butterflies fly in the daytime.

(*b*) Moths have thicker, stubbier bodies than the butterflies.

(c) The moth holds its wings like a roof over its abdomen, when in repose; the butterfly holds its wings vertically.

(d) The pupa of a moth is usually inclosed in a co-
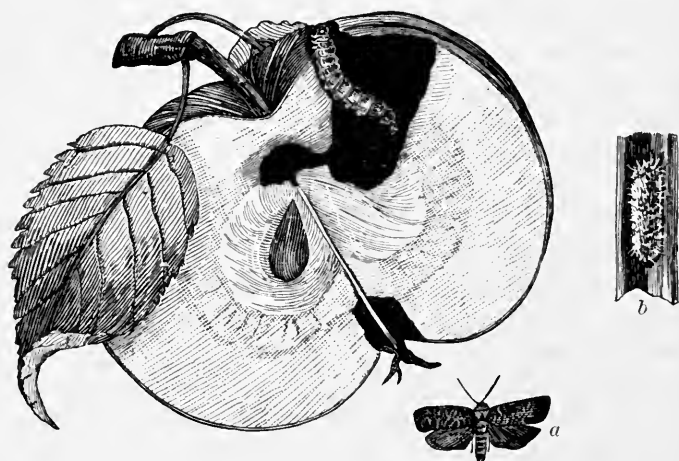
FIG. 161. — Section of Wormy Apple.
a, codling moth; b, cocoon.

coon which is made of silken threads; the pupa of the butterfly is naked, having no covering, and is called a chrysalis.

The Codling Moth. In its larval state this is called the apple worm. It does great damage to apples by making them wormy and causing them to fall from the tree. In appearance this moth is a small, brown-winged insect. It lays its tiny eggs on the young green apple toward the blossom or calyx end, or on the leaf. As soon as the egg hatches, the young larva eats some of the tender fruit and then proceeds to burrow a hole to the core of the apple, nearly all entering at the

calyx. To get rid of its surplus food it bores a hole through the side of the apple and leaves the particles of food on the surface. This hole furnishes a means of exit from the apple when the apple falls.

A thorough spraying with one of the arsenical insecticides will greatly reduce the destructiveness of the

FIG. 162.

Stalk of cotton showing the egg (*e*), larva (*a*), pupa (*b*), and adult of the cotton worm moth. (After Herrick.)

codling moth if given just as they hatch. To accomplish this the trees should be thoroughly sprayed just as the petals are falling. A second spraying should be given just as the calyx commences to wither, and ten or twelve days later a third spraying. Careful orchardists spray their trees frequently, not to rid their trees of this and other harmful insects that infest them, but to keep them out entirely. An early spring spraying in addition to those described will usually maintain orchards free from moths. All windfalls should be gathered daily, and fed to hogs or other stock so that the worms may not be allowed to develop into moths.

The Cotton Moth. This moth in the caterpillar form is called the "army worm," because of the large numbers that march together to devastate a field of cotton. The eggs are laid on the leaves of the cotton plant. When hatched into a caterpillar, it will, if unmolested, soon eat the leaves, but its destructive effects are largely due in the case of oats to the fact that it eats off the little stems of the panicle that support the grains.

The cabbage worm eats cabbage leaves. The eggs are laid by a small white butterfly in the spring. Very little can be done to destroy the adult butterflies, but if the worms are on the cabbage an early spraying of Paris green or arsenate of lead will poison the larvæ. Later the cabbage leaves may be covered with flour, which largely prevents the destruction of the leaves by the worm.

Bees and Ants (*Hymenoptera*, membrane-winged). — This order, including bees, ants, saw-flies, gall flies, ichneumon flies, and the imported currant worm, is characterized by having two pairs of membranous

wings with but comparatively few veins. The head
is large and the mouth parts are formed for biting and
lapping. The female possesses a sting, an ovipositor,
or a saw. The metamorphosis is complete.

Imported Currant Worm. This is not a true cater-
pillar, but is the larva
of a small fly. The
larvæ eat the leaves of
the currant and of the
gooseberry. When full
grown it spins a cocoon
in the rubbish or on the
stems or leaves of the
bushes. Paris green may
be used as an insecticide
before the fruit is ripe,

FIG. 163. — Imported Currant Worm.
(After Washburn.)

but later in the season dry hellebore may be dusted on
the leaves when they are wet.

Bees live in colonies. In their wild state they find
their homes in the trunks of trees, in rock crevices, or

Worker   Queen   Drone
FIG. 164. — Honeybees.

in other cavities, but man has provided hives as the
homes of bee colonies so that they may be manipulated,
and the stores of honey easily collected for his profit.
A colony of bees consists normally of a queen bee,

the mother of the colony; thousands of worker bees, which are undeveloped females that lay no eggs, but gather the stores of honey and care for the young; and, during a part of the year, males, which are called drones, to the number of a few hundred. These three classes may be easily recognized in the colony. The queen bee has a longer and more slender body than the drones or the workers. The drones are larger than the workers. Drones are stingless. The queen and the workers have stings, but the queen uses hers only on other young queens, so that the worker bee's sting is the only one to be feared.

The combs are made of hexagonal cells of somewhat irregular size and shape. The comb includes cells for the development of brood and young bees and for the storage of honey. The cells used in rearing worker bees are about one fifth inch across, and those used for rearing drones and for storing honey are about one fourth inch across. Artificial foundations for combs, made from beeswax, are provided by bee keepers so that the location and size of the combs may be under his control.

A hive of bees ready for work in the spring has its thousands of workers bringing in early pollen and honey. The queen begins to lay eggs in the worker cells. These in time develop into white larvæ, which, growing, fill the cells. The cells are then capped over. In twenty-one days after the egg is laid, the worker bee emerges from the cell. It is usually two weeks later before she does any honey gathering. As the colony increases and honey is stored, the queen begins to lay eggs in the larger cells. These develop into males. After a time the workers begin to build queen cells over certain fe-

male larvæ. These are larger than any other cells in the hive and hang on the hive vertically. In appearance they resemble a peanut. When the larvæ in these cells have grown to full size they are sealed up and the colony is ready for swarming.

Swarming consists in the departure of the queen bee with a part of the workers. They leave to seek a new home and to continue raising brood and storing honey. They leave behind all the stores of honey except what they can carry in their honey stomachs and the brood with some queen cells from which will come the new queen for the part of the colony of workers left behind. After about nine days the new queens are ready to come from their cells. The first one to emerge is the queen of the colony, and she usually destroys the queens in the remaining cells.

In about five days the queen leaves the hive to mate with a drone in the air. She soon returns and egg laying is commenced. The queen does not leave the hive except at mating time and when the colony swarms. At the end of the honey season the drones are driven out or carried out of the hive by the workers.

Bees collect three different materials, — *nectar* from which the honey is made, *pollen* of plants that furnishes a part of the food for the larvæ, and a resinous substance called *propolis*, or bee glue, that is used in stopping crevices in the hive and in cementing the wax cells together.

The worker gathers nectar from many kinds of wild and cultivated plants. This it laps up with its long tongue, then passes it into the first stomach or crop. Here the nectar undergoes some changes, preventing fermentation, and then such part of it as the bee does

not need for its own sustenance is regurgitated into the honey cells of the comb.

The pollen and the propolis are collected in receptacles on the outside of the hind legs. These pockets are filled by a rapid movement of the mandibles and of the other legs. The wax is an excretion from the body which collects in little scales on the under side of the abdomen.

The work of the hive is nicely apportioned among its inmates. Normally the egg laying is done by the queen. All of the inside work, such as wax building, care of the brood, and cleaning, is done by the younger workers — those less than seventeen days old. The work of nectar and pollen gathering is performed by the older workers.

The general prime object of the beekeeper is to make as large and as strong a colony of bees as possible for each hive before the large supply of nectar is produced, so that when the flowers are in full bloom a large amount of honey may be obtained. It may be necessary to feed the bees a sugar sirup so that a vigorous brood may be raised early in the season.

The life of the worker bee is usually not more than eight months. Her active life wears out her wings and makes it impossible for her to collect materials for honey. The queen may live two to five years.

In the north the hives should be well stored with honey in the fall so as to furnish the bees with food for the winter. At this time the hives are usually closed and put in a dark cellar or other storage free from the extremes of temperature. There the bees will live in a quiescent state till the next spring.

Besides the common black or brown bees we have

the Italians, Caucasians, Cyprians, Syrians, and Carniolans. The black bees are very spiteful, difficult to handle, and are not first-class workers. The Italians are a great improvement. Nearly all of the bees kept in this country are Italians or some cross of the Italians with the black bees. They are not so difficult to handle and are more profitable. The Caucasians and the Carniolans are still more gentle than the Italians.

Ichneumon Flies. — The ichneumon flies represent a class of flies belonging to the order Hymenoptera that are of great service in destroying certain injurious moths and other insects. They lay their eggs in the body of a moth or other insect; the larva lives on the juices of its host and may even pass the pupa stage within its body.
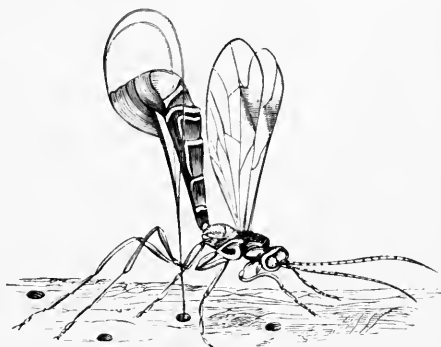
FIG. 165. — Ichneumon Fly.

Figure 165 shows an ichneumon fly that bores a hole with its ovipositor in wood and deposits its egg in the burrow of some insect tunneling in the wood. When the egg is hatched, the larva seeks the pupa of the other insect and lives upon it.

SPIDERS (*Arachnida*)

This large division of the animal kingdom includes spiders, scorpions, tarantulas, and mites. Let it be remembered that, although these animals are many of

them very small, they are not insects and of course are not bugs.

The bodies of animals of this class are generally divided into two segments and have four pairs of legs. They have no antennæ and but a partial metamorphosis, or none at all. The animals of this class, except the mites, give farmers very little trouble.

Mites. — These little animals have the appearance of having the whole body included in one sac-like piece. When they are full of the blood of the animal to which they have attached themselves, these sacks become quite distended. The chicken mites, or chicken spiders, are a great pest in the poultry house. These little mites remain in cracks and crevices in the poultry house during the day, but at night, while the poultry are roosting, they come out to suck the blood of their victims. They sometimes remain in hiding on the body of the chicken where the feathers are thick.

If the roosts and interior of the poultry house are well soaked with cresol or with kerosene, these troublesome mites will be exterminated.

Ticks. — These animals are like mites, but are usually much larger.

The southern cattle tick is a parasite on cattle, and is the means of conveying the disease known as the Texas fever from one animal to another.

When the female tick is ready to lay her eggs, she drops from the animal to which she has attached herself and deposits them on the ground. The eggs soon develop into seed ticks, which fasten themselves to cattle that may be within reach. Here the seeds remain till they mature. Passing the cattle through

vats filled with one of the coal tar dips of proper strength will destroy the seeds and the ticks.

FIG. 106. — Southern Cattle Tick and Eggs.
Above, magnified; below, natural size. (Herrick.)

The so-called sheep tick is not a tick, but is a wingless fly which passes its entire life on the sheep. By careful government inspection and compulsory dipping this pest has been largely eliminated.

ANIMALS IN OTHER CLASSES

Toads. — These homely animals are of great benefit to the farmer and gardener. They are entirely harm-

less and live almost entirely on insects, worms, and spiders, an incredible number of these being consumed by the toad in twenty-four hours. He fills his stomach four times each day, and of all the insects eaten, nearly three fourths are harmful. If possible these helpful animals should be increased in number. Their adult life is spent on the land, under a stone or in a hole in the ground during the daytime, but in active service at night. The eggs are laid in long strings attached to the grass or weeds in ponds or puddles of water. The eggs hatch into tadpoles, or polliwogs, which breathe in the water by means of gills.

The polliwogs soon develop hind legs, then fore legs, and lastly true lungs, enabling them to breathe in the air. They then leave the water for the land.

Birds. — Nearly all birds when young in the nest are insectivorous, the mother bird catching the insects and feeding the young. Some birds are insectivorous also throughout their lives, others live on fruits and grains, and others on larger forms of animal life. All birds have a favorite diet, but if for any reason the food of their choice is not abundant, they will sustain life on other food.

Among the most useful wild birds to farmers are the following: robin, quail, or bobwhite, bluebird, phœbe, house wren, barn swallow, meadow lark, grass finch, chickadee, downy woodpecker, yellow hammer, or flicker, and night hawk. Such birds should be protected in every way and should be encouraged to multiply.

There are a few birds that do more harm than good, and these should be held in check.

The English sparrow has so increased in numbers that it has become a pest, and, besides, has driven away

many more desirable birds. This bird lives almost entirely on grain, and it should therefore be suppressed. The catbird is a fruit eater, and the crow destroys much corn during the spring days following its planting. Their numbers should be diminished.

Hawks and owls often carry off young chickens, hence should not be allowed to increase in numbers. Owls, however, probably

FIG. 167. — English Sparrow, Male and Female, taking Possession of Nesting Boxes provided for Native Birds. (Farmer's Bulletin, 383.)

pay for a part of the loss which they occasion by destroying field mice.

Gophers, woodchucks, rabbits, skunks, mice, and rats are all destructive to the crops of the farm, but none of them becomes a pest beyond the control of the farmer, though the total amount of loss through them in one year would doubtless be expressed in many millions, if it could be accurately determined.

CHAPTER VII

FARM ANIMALS

THAT animals are an absolute necessity to general farming if the fertility of the land is to be maintained at reasonable cost has been frequently referred to in the preceding pages. Animals return to the land in the form of manure fully half as much as they take out of it as food, besides furnishing products that yield large profits.

The selection, breeding, and care of these animals, or animal husbandry, is, therefore, an important subject for the farmer to study, even if he is only a general farmer and not engaged in raising animals or their products for commercial purposes.

CATTLE

" The farmer seeks or should seek an animal which, in view of climate, soil, and his practice of husbandry, shall return him the largest profit, whether in the dairy, under the yoke, or in the shambles."

There are two distinct types of cattle: the dairy and the beef, but not all cows are distinctly one type or the other. Some are what are known as *general purpose*, or *dual purpose*, cows; that is, animals which are members of a specially developed milk-producing family from one of the beef breeds. Such cows are usually of large frame, are easily kept in good flesh, fatten soon

when not milking heavily, and have large calves, which are profitable for veal or for growing as steers.

In addition to the above-named types, there are many common cows, familiarly termed *scrubs*, which belong to no type, being neither good milk producers nor good meat producers. The first cost of these cows may be small, but they are the most expensive in the end.

The Beef Type

The aptitude to take on flesh is of vital importance in this type, for the best beef animal is the one that carries to the block the highest excellence and the most profit. The general beef type animal is low, broad, deep, smooth, even, and rectangular in form. It is of great importance, when considering profits, to have an animal that puts on a thick, even covering of the right kind of meat in the parts that make high-priced cuts.

The Shorthorn, or Durham. — The most common beef-type animal is the Durham, an English breed formerly called shorthorn. As they produce milk of good quality and quantity, they make one of the best dual purpose cows known.

A breed derived from the shorthorns, the Polled (hornless) Durham, originated in this
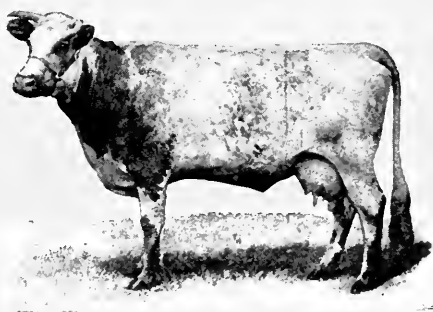
FIG. 108. — Durham.

country. The color of these two breeds is variable, being sometimes red, sometimes white, sometimes a

combination of red and white, and sometimes a mixture of the two colors, or roan.

Beef animals of large bodies were originally considered the most desirable, regardless of age or of other qualities. The early breeders of the shorthorn sought to develop a breed that should have some refinement of bone and early maturing qualities while still retaining considerable growthiness.

The Colling brothers, who lived in England, are often spoken of as the founders of this breed. The improvement made by these men, and continued by the Booth family, Thomas Bates, and Amos Cruikshank, dates from about the year 1780.

Thomas Bates devoted his energies toward improving the dairy qualities of the breed. In this he was quite successful. We have many herds of *milking shorthorns* in this country as a result of his efforts to improve the milk production of shorthorns.

Amos Cruikshank of Aberdeen, Scotland, developed a type of shorthorn that is known as *Scotch* and is probably the most popular of any type of the breed. The Scotch cattle are " broad and thick of back, deep and compact of body, short of leg, heavy in flesh-producing quality and early maturing."

The Herefords, another English breed, produce little milk, but are a hardy type that have thriven well on western ranges in the past thirty years. They may be recognized by their uniformly white heads and red bodies. They are sometimes called the *white faces.* Their coats are thick and curly and the breed make good rustlers. They do not stand confinement so well as the shorthorns. The dewlap is large and the flesh is not always very thick on the rounds, but it is

evenly spread over the shoulders and loins, and its quality is very good. Many of these animals attain

FIG. 169. — Hereford.

a size equal to that of the shorthorn, from 2000 to 2300 pounds in weight.

The Aberdeen Angus. — The past two decades have seen the introduction of the Angus cattle from Scotland, sometimes called the Polled Angus because they are hornless. They are for this reason also called *doddies*. They are black, the hair is smooth, the frame is large and the bones fine. They are more cylindrical in form than

FIG. 170. — Aberdeen Angus.

the other breeds of cattle. The flesh is very smoothly placed over the body and contains about the right

proportions of lean and fat. They are great favorites with the butchers, as they dress out a large proportion of meat.

The Galloway is a breed originating in Scotland, and

FIG. 171. — Galloway.

noted especially for its hardiness and the fine quality of its meat. These animals are hornless, and are covered with a black, curly coat of long hair. The hide is some-times used for robes. The Galloway is not so large as the breeds heretofore described and does not reach maturity at an early age.

The Red Polled breed originated in England. As their name indicates, they are hornless and are red in color. They are of medium

FIG. 172. — Red Poll.

size and give a fair quantity of milk Some individuals of this breed give a very good yield of rich milk and they are prized highly by those who desire a breed that

will fatten readily when dry and yet may be used as a dairy animal.

Notes. — *The Devon* is a small, red animal of the beef type, although it ranks quite well as a milk producer. It is not popular in the United States. It is one of the oldest breeds, and has been much used for draft purposes. Devon oxen were great favorites on the farms of the eastern states when a yoke of cattle took the place of a team of horses.

The Brown Swiss is one of the chief breeds of Switzerland. There are a few herds of this breed in America, but it has not attained to any great degree of popularity. The Brown Swiss is gray or brown with a *mealy* muzzle. Its disposition is

FIG. 173. — Brown Swiss.

dull, the hide is thick, and the bones are heavy. As a milk producer it is a great favorite in Switzerland, but it has not proved to be a very economical animal for either milk or beef production under conditions found in this country.

The Simmenthal cattle, native to Switzerland and spotted yellowish red and white, are very much in evidence in central Europe. They are thought to be the foundation for some of the important breeds of cattle found now throughout the world, some of which, by years of breeding for dairy purposes, have developed into some of the best dairy breeds.

Breeding. — Good breeding and continuous good feeding are necessary to the development of the best characteristics in any beef-producing animal. The steer that will best repay fattening, that is, will lay on flesh of the best quality in places that will give the highest priced cuts, shows a blocky frame, stoutness of

build, short, straight legs, wide back and loin, well-sprung ribs, fullness back of the shoulders and in the flanks prominent brisket, full neck vein, wide chest and well-rounded body, good, soft, mellow skin, fine hair, strong vigorous head, clear, full eye, and quiet temperament. Such an animal under good feeding (see Chapter VIII) should make a high block test, that is, yield a high percentage of valuable cuts of meat.

Cutting Beef. — Figure 174 shows the Chicago wholesaler's and retailer's method of cutting a beef carcass. The porterhouse and sirloin steaks are cut from the loin.
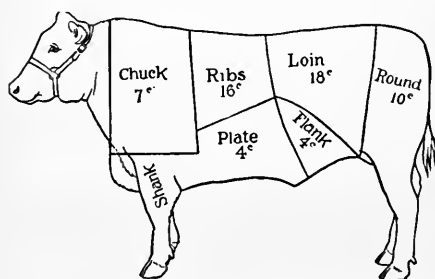
FIG. 174. — Cuts of Beef and Relative Prices.

The porterhouse steaks bring the highest price to the retailer, the rib roast and sirloin cuts ranking second; hence the animal giving the largest proportion of choice cuts at these points will yield the best price to the farmer. The loins and ribs of the wholesaler's cut, which correspond to the above-named cuts of the retailer's, also bring the largest returns.

It has been demonstrated by actual tests that the neck piece is as toothsome and nutritious as porterhouse if it is as suitably prepared, but it brings the lowest price. When porterhouse sells for 20 cents, the neck brings only 3 cents a pound.

By-products of Beef. — There are so many of these products that mention can be made of only a few. Leather, glue, tallow, oils, soap, fertilizers, and oleo-

margarine are among the most important manufactured articles that the carcass yields. The hides, the horns, the hoofs, the hair, the bones, the blood, — in short, all parts of the animal are used in making some useful product.

THE DAIRY TYPE

The dairy type of cattle have the tendency to manufacture their food into milk. On account of this tendency the true dairy cow has a spare, angular form. The neck is long and thin, the shoulder is sharp and the hip points are prominent. The ribs are long and of such shape as to make a deep barrel, giving large lung capacity and a body capable of holding a large quantity of bulky food. The udder is large, well shaped, and extends up high between the legs behind. These characteristics give rise to the triple wedge form as shown in Figure 175.
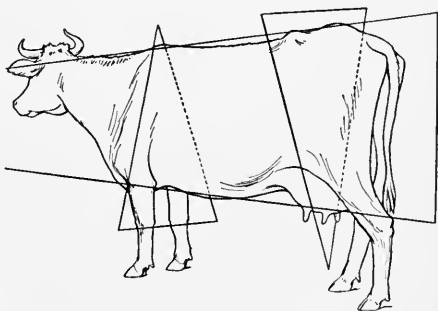
On the lower side of the abdomen are found the milk veins which take the blood from the udder to the heart. These veins are very

FIG. 175. — Triple Wedge.

prominent and have many branches in the good dairy cow. They pass up into the body in holes toward the front of the abdomen, called the *milk wells*. Large milk wells are an indication of great ability in milk production.

Although some dairy breeds produce beef of acceptable quality, they are not usually profitable as beef

producers. On the market the carcasses of dairy cattle bring the lowest prices.

The Jersey has its home in the Island of Jersey in the English Channel. Here the cattle have been bred
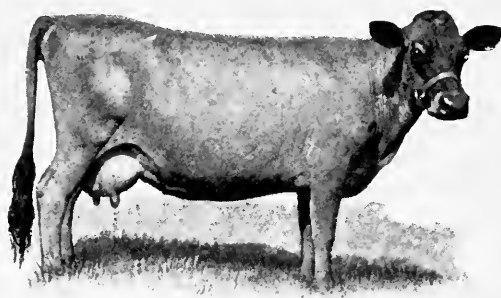
FIG. 176. — Jersey.

pure for more than a century. Since 1789 it has been unlawful to bring to the Isle of Jersey cattle of any other breed except for immediate slaughter. The Jersey has been bred for production of butter fat. In competitive tests it has shown an ability to produce a large quantity of butter very economically.

The color of the Jersey is usually fawn color, but it may be a squirrel gray or black. The nose is usually dark colored.

There are more Jerseys in the United States than of any other dairy breed. It is of small size and is often kept in cities or villages by families desiring a small cow giving rich milk. In disposition the Jersey is nervous and requires careful handling for the best results.

Note. — The milk of the Jersey will average about 4.5 per cent butter fat and often will go as high as 6 and 7 per cent. The butter fat globules are very large and the cream made up of these globules separates from the rest of the milk very easily and completely, leaving the milk without cream quite devoid of richness. The skim milk has a watery or blue appearance.

The Guernsey has its native home on the Island of Guernsey, not far from the home of the Jersey. The Jersey and the Guernsey are sometimes called the Channel Island cattle, and were formerly known as the Alderney, although the term Alderney is properly applied to cattle from an adjoining island of that name which are now registered as Guernseys. The Guernseys are very similar in general conformation and productiveness to the Jersey. They are

FIG. 177. — Guernsey.

protected in their purity by the same kind of laws as are in force in the Island of Jersey. Their bodies are somewhat larger and coarser than the Jerseys and they are not so nervous in disposition. They are of a yellowish or reddish fawn color and usually have white markings. The limbs and the under part of the body are often white. The nose is flesh colored. The skin is a deep yellow. This color is especially noted in the ears and in the end of the tail.

The best Guernseys give a large quantity of very rich milk. The cream is of a rich yellow color and when made into butter does not require the addition of butter color.

The number of Guernseys in the United States is not large, but the breed is gaining rapidly in popularity.

The Holstein-Friesians are natives of Holland. They are large, black and white cattle, and are producers of large yields of milk. The milk is not so rich

FIG. 178. — Holstein.

as that of the breeds heretofore described. It averages about 3.25 per cent butter fat. The fat globules are very small and do not rise to the surface so readily as in the milk containing larger fat globules. The milk is easily digested and is especially valuable for infants. These cattle are used in dairies supplying milk to large cities.

Although the Holsteins are not used for beef production on account of not dressing out a large percentage of high-priced meat, the calves of this breed are in much favor for veal.

In disposition the Holsteins are quiet. They take conditions as they find them and seem to be contented, giving better results under adverse circumstances than any other dairy breed.

Note. — The name *Holstein* is derived from a province in Germany by this name, situated about 100 miles east of Holland. The Dutch cattle are popular there as they are throughout northern Germany. *Friesian* is derived from Friesland, a province in Holland. The Dutch black and white cattle were imported from both of these provinces and exploited as separate breeds in the United States, one the Holstein and the other the Friesian. When the breeders found that

the two breeds had the same origin, namely, Holland, they united and called the breed the Holstein-Friesian. More properly, it should be named as it is in Europe, the Friesian.

Dutch Belted cattle are somewhat smaller than the Holstein-Friesian breed. They are characterized by having a broad belt of white extending about the body otherwise black. They have no qualities that make them especially valuable to dairymen and are bred largely because of the novelty of their marking.

The Ayrshire is a breed originated in Ayr, a county in southwestern Scotland. The Ayrshire cow is a good milk producer, but the milk is not rich in butter fat. The fat globules are small, and the milk contains just about the correct proportions of curd-forming substances to make cheese. On this account, the Ayrshires are largely used to furnish milk for cheese production. These animals are not so strictly of the dairy type as the others described. They put on a good supply of

FIG. 179. — Ayrshire.

meat and are more valuable to the butcher than other dairy breeds. Their color is red, brown, or white. Their disposition is timid, a characteristic especially notable in the bulls.

The Kerry cattle originated in western Ireland. They are the smallest of any breed. The *Dexter-Kerry*, a cross with the true Kerry, weighs but 400

pounds. These small animals are accustomed to adverse conditions and produce a large quantity of milk for their size. Their color is black. They are not found to any extent in America.

Note. — The *French Canadian* cattle originated in the province of Quebec. They are black in color and resemble the Jerseys in conformation. They are a rugged breed of cattle, adapted to roughing it in a cold climate. They give a good supply of milk, which they produce very economically.

The Cow as a Machine. — There can be no question that the breeding of cattle for milk production has greatly increased the ability of certain animals to transform the food given to them into milk.

If one is selling butter or milk on the test, or the number of pounds of butter fat that it contains, it is good business sense to keep such cows as will produce most economically the product that one is selling. A cow should be considered a machine for the production of milk or butter fat. If she can produce 4000 pounds of milk in a year, she may be kept at a profit; if she produces less than that amount, she is probably being kept at a loss and should be disposed of regardless of her beauty or her breed. The farmer should weigh the milk of each cow in his herd and determine which cows are profitable and should keep no others. More than one half of the cows in many herds are being kept at a loss. Weighing the milk of each cow will determine which cows to eliminate.

Note. — *Some butter-fat records.* The average production of butter fat for the cows in the United States is less than 145 pounds each. An elimination of unprofitable cows would easily double the average production. The following are some of the most notable records of dairy cows:

Colantha 4th's Johanna holds the world's record for a year for milk. She is a Holstein and gave 27,432.5 pounds of milk and 998 pounds of butter fat.

The world's champion Jersey is **Jacoba Irene**, who gave 952 pounds and 15 ounces of butter fat in one year. Many consider her the greatest dairy cow in the world, for she made high records for three years in succession.

The champion Guernsey of the world is **Dolly Dimple**, who gave 906.87 pounds of butter fat in one year when she was but $2\frac{1}{2}$ years old.

Yeksa Sunbeam, a Guernsey, had been the world's champion for some time. She produced 857.15 pounds of butter fat in one year.

The value of a dairy cow. The following table shows the value of a dairy cow based on production and cost of

FIG. 180. — Appliances for Weighing Milk.

keep. The table is made on the basis of 4 per cent milk; that is, that the milk contains 4 per cent of butter fat. If, after testing the milk, it is found to contain more or less than 4 per cent butter fat, profit may be determined by adding or subtracting the amount of such difference at 27 cents per pound.

Value of Cow, based on Production and Cost of Keep

1. Value when first fresh	$40.00	$45.00	$50.00	$60.00	$70.00	$80.00	$90.00
2. Value for beef at end of life . . :	$27.00	$25.00	$25.00	$25.00	$25.00	$25.00	$25.00
3. Lb. of milk produced .	4000	5000	6000	7000	8000	9000	10,000
4. Lb. of butter fat . . .	160	200	240	280	320	360	400
5. Lb. of skim milk . . .	3400	4250	5100	5950	6800	7650	8500
6. Value of butter fat at 27¢ a pound	$43.20	$54.00	$64.80	$75.60	$86.40	$97.20	$108.00
7. Value of skim milk at 20¢ a hundred . . .	$6.80	$8.50	$10.20	$11.90	$13.60	$15.30	$17.00
8. Value of calf {Heifer/Bull} Av.	$4 }3.50 $3	$5 }4.00 $3	$6 }4.50 $3	$8 }5.50 3	$10 }6.50 $3	$13 }8.00 $3	$16 }12.00 $8
9. Value of manure at $1.50 a ton	$14.50	$15.00	$15.50	$16.00	$16.50	$17.00	$17.50
10. Cost of feed	$38.00	$40.00	$42.00	$44.00	$46.00	$48.00	$50.00
11. Cost of labor	$18.00	$18.00	$19.00	$19.50	$20.00	$20.50	$21.00
12. Insurance, veterinary, medicine, depreciation, buildings, etc. . . .	$11.00	$12.40	$13.54	$14.65	$17.75	$19.80	$24.00
13. Value of all products .	$68.00	$81.50	$95.00	$109.00	$123.00	$37.50	$154.00
14. Total expense	$67.00	$70.90	$74.57	$78.15	$83.75	$88.30	$95.00
15. Profit (keep none at a loss)	$1.00	$10.60	$20.46	$30.85	$39.25	$49.20	$59.50

Circular No. 134, Ill., W. J. Fraser, head of Dairy Division.

Care of Dairy Cows. — Modern methods of dairying call for the best care of the dairy herd. The best conditions demand a separate building for the cows on the ground level, with no manure cellar beneath, the barn being light, dry, high, and roomy, with ample ventilation provided. Individual stalls wide enough for the comfort of the cow and the milker are deemed essential. Some dairymen object to any form of stanchion for cows, substituting for it a wide strap or light chain about the neck as allowing more freedom of movement.

Dairy Products. — The care of milk and the manufacture of its products, butter and cheese, especially butter, are among the most important affairs of the farm, even though the growth of creameries and cheese factories is taking away the manufacture of the two products from the farm. There still remain many farmers who make butter for market and home consumption, but cheese is now almost entirely a factory-made product.

Whether the butter is made on the farm or in the creamery, the milking of the cows and the care of the milk are farm business demanding the greatest nicety and pains.

Yield of Milk. — From what has been said of the different dairy breeds, we know that the amount and quality of milk obtained from a cow depend somewhat upon the breed. But this is only one of the determining factors. Good feeding will affect the yield of milk so greatly that it is held next in importance, if not equal to breed in affecting results (see Chapter VIII). The next factor entering into the milk yield is the care of the animal in housing as to space, cleanliness of sur-

roundings, temperature, light, and ventilation. A last
element in securing rich yields, both in quantity and
quality, is the milker himself.   If quiet, even-tempered,
and gentle, he will get more milk than if the reverse
are his characteristics.   If he is a rapid milker, he will
get more and richer milk as a result, for the expert
milker gets the most butter fat from the cow.

Pure Milk

The only way milk can be kept pure is through
cleanliness. The barn must be clean, the cow must be
clean, the milker must be clean, the utensils must be
clean. Bacteria abound everywhere, in the dust of
the barn, on the animal milked, on the person of the
milker, and unless great care is taken, they enter the
milk in large numbers. These are not necessarily
disease-producing bacteria, although such may also
be present, but they are organisms harmful to the sweet-
ness and purity of milk. They multiply rapidly in
warm fresh milk, and unless preventive measures are
taken, soon cause the milk to sour. Cooling the milk
while it is perfectly fresh will not kill the germs, but
it will retard their growth and increase, and this pre-
vents its turning sour so soon. Pasteurizing the milk,
that is, heating it to 130°–160° F., keeping it there
25 minutes, and then rapidly cooling it to 50°, will
kill most of the germs and keep the milk sweet for some
time, especially if it is carefully sealed in air-tight vessels.

Composition of Milk. — The average composition
of the milk of the cow in this country is as follows:
water, .875; milk sugar, .0475; fat, .036; casein, .029;
mineral matter, .0075; albumin, .005.

The fat in milk is the constituent that makes butter.

It floats in the milk in globules, varying in size according to the breed and the feed and the individual cow. The fat rarely reaches 7 per cent of the bulk of the milk, the highest grade dairy breeds, like the Jersey and Guernsey, averaging about $4\frac{1}{2}$ per cent.

Cream. — When milk stands for a short time, the fat rises to the top in the form of cream. Formerly milk was placed in shallow vessels and the cream was skimmed off and made into butter. By this method one fourth of the butter fat is lost in the skimmed milk. The deep-setting system is now more extensively practiced. Cans nearly two feet deep are used. They are set from 12 to 24 hours in water 8 degrees to 10 degrees above freezing point. A conical dipper is used for skimming, or a faucet in the bottom is opened and the skim milk drawn off and then the cream. By this method only one tenth to one fifth of the cream is lost in the skimmed milk.

The method most commonly used, however, and the one that results in the least loss of butter fat is the centrifugal separator, by means of which the cream and milk are separated. The fresh milk pours in a continuous stream into a revolving bowl. The milk, being heavier than cream, is thrown to the outer part of the bowl, where there is placed an opening to carry it off. In the center is an opening through which the cream passes. A good separator loses only about .0003 of fat in skim milk or one fiftieth of the total amount of butter fat.

Casein. — This is the ingredient in milk that forms the curd when milk sours. It is the foundation of cheese, as butter fat is of butter, forming about one third the bulk of the finished product.

Testing Milk. — All creameries now pay for their
milk on the basis of the percentage of butter fat present as revealed by the Babcock test. This is a device invented by Dr. Babcock of the Wisconsin Experiment Station.
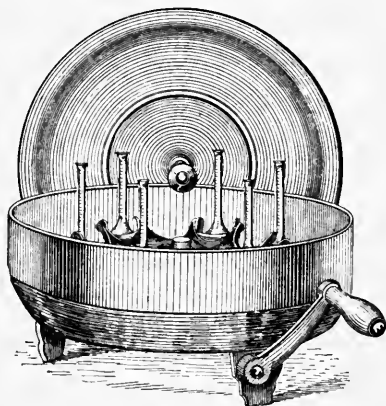
FIG. 181. — Milk-testing Machine.

Note. — 17.6 c.c. of the milk to be
tested is put into a test bottle. An equal
amount of sulphuric acid is added. This
dissolves all the solids of the milk excepting fat. The mixture is shaken thoroughly
until it becomes of an even dark brown
color. The bottle is then put into the
machine and is made to revolve rapidly
for five minutes. The machine is then
stopped and the bottle filled to the neck
with hot water, then whirled again for
three minutes, then filled again with hot
water to about the 8 mark on the neck. It is now whirled again

17.5
c.c.

Measure for Acid

Pipette for measuring Samples of Milk

17.6
c.c.

10
9
8
7
6
5
4
3
2
1
0

Test Bottle
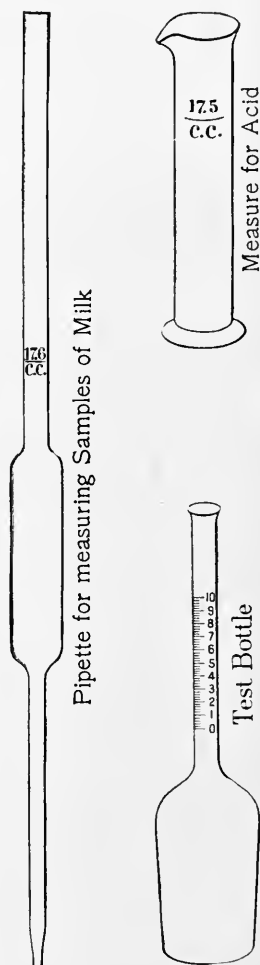
FIG. 182.

for two minutes, then taken out and the percentage of fat read from the neck of the bottle, which has a scale graduated from 0 to 10.

The dairyman who wishes to know whether individual cows are profitable, or the comparative value of his different cows, can get this information by weighing and testing the milk for a given period. If the test of a given cow taken successively shows an average of 5.2 per cent, this means that in 1000 pounds of her milk there are 52 pounds of butter fat. This will make about 60 pounds of butter (one sixth more). Knowing the cost of the cow and having ascertained the cost of feeding, he can compute the cost of butter.

Horses

There are two classes of horses of interest to the farmer, *draft* horses and *carriage* horses. The latter class includes the American trotting horse and the English coach horse.

These two great classes of horses have strongly marked characteristics which make them easily distinguished from each other. The best draft horses have good feet and legs, a well-developed body, deep, wide, and short, and weigh from 1800 pounds upwards. The hoofs are large, round, and wide at the heel. The legs are rather short, and are well set under the body. The Percheron from France, Belgian from Belgium, Clydesdale from Scotland, and Shire from England are four of the best known breeds, the first being the most popular in this country. Comparatively few farmers in the United States purchase or breed pure draft horses. Their preference is for a horse of mixed type, not so heavy as the draft horse nor so light as the trotter.

The Percheron. — This breed derives its name from a province in France, La Perche, where it originated. The name Norman has often been applied to the breed also. Their intelligence, activity, fine bone, and sound feet contribute to their popularity. The legs are clean of long hair and the color is dappled or mottled gray or black, although some browns and bays are also found among them.

FIG. 183. — Percheron.

The Clydesdale. — This breed of draft horse is the next most popular in America. It originated in Scotland where it is the recognized draft breed. The long hair on the lower part of the leg, called the feather, is one of the distinguishing marks of the breed. The Clydesdales have long bodies and are noted for their rapid walk. The color of the
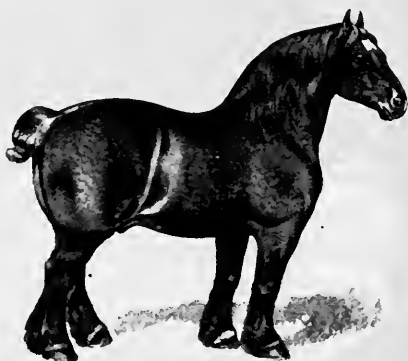
FIG. 184. — Clydesdale.

breed varies, though it is usually bay or brown, with some white marks on the face, and all or a part of the legs white up to the knees or hocks.

The Shire is a large horse of the draft type. It has a large, round body, short legs, and a large, flat foot. It is the popular draft horse of England. In action it is somewhat slow, in disposition, mild. The shire has a feather of long hair extending from the hock and the knee to the hoof. Its color is usually bay or brown with white lower legs and a white marking on the face and forehead.

The Belgian. — These draft horses are bred in Bel-

FIG. 185. — Belgian.

gium, where the government gives direction and encouragement in their breeding.

This breed is characterized by its blocky build, with the broadest back and the deepest barrel of any horse. Its legs are short and have no long hair, its feet are quite small for its s ze, and its movements are not very active. The popular color is chestnut, but bays, browns, and roans are frequent. The breed is gaining in favor in the United States.

The Suffolk. — This is a breed originating in Suffolk County, England, and furnishes the heavy horses for farm work in that country. It has been called the *Suffolk Paunch* because of its paunchy body, but the breed is not so large as the other breeds described. The Suffolk has small ears, short legs with no superfluous hair, and a deep body. Its color is always chestnut.

Carriage Horses. — The carriage, or coach, horse is an English type from which the American trotter has been developed. The ideal carriage horse must be of good size, 15.3 to 16.2 hands high, weighing 1200 pounds and upwards. He must have a well-shaped head on a long, well-arched neck. His action must be free from paddling or rolling, yet show speed. The (1) English Hackney, the (2) German Coach, and the (3) Cleveland Bay are breeds more or less popular, but horse. breeders in this country are fast developing a distinctively American type of carriage horse which possesses points superior to any of these well-known breeds.

The trotter, an American breed, has a small head, long, sloping shoulders, rather long legs, hind ones strong, smooth hoofs, and large nostrils. This horse is bred largely for speed. (4) The Hambletonians, Clays, and Morgans are the most popular of the trotting families.
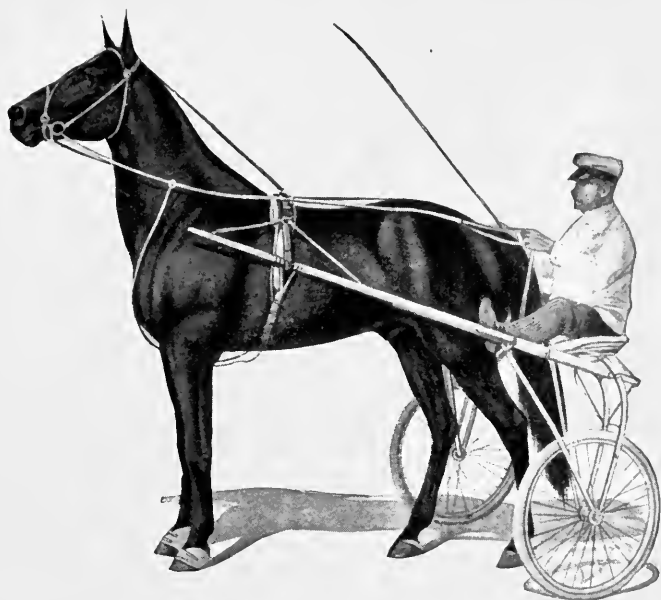
Fig. 186. — Dan Patch.

The saddle horse, a breed for which Kentucky, Virginia, and Missouri are noted, is the progeny of the English thoroughbred, the latter bred from the famous Arabian horses and native stock. The American saddle horse is used either as a saddle or as a harness horse. There are two classes, the plain-gaited or walk, trot, and canter horse, and the American-gaited horse, which shows at least five distinct gaits.

Notes. — *The English Hackney horse* is a "high stepper," used as a fancy carriage horse. It has a blocky form, full breast, short legs and back. It has a neat neck and an intelligent head. The color is bay, brown, black, or chestnut, the latter being the most popular color at present. Its gait is very attractive — the "feet are clear of the

ground and are strongly and actively raised to the knee, while the hock

FIG. 187. — English Hackney.

is carried forward under the body with much grace, strength, and action."

The German Coach. This breed from Germany is not very well established as to type. There are four types, in fact, depending largely on the special use of the horse. In Germany many horses of this breed are used as saddle horses. It also makes a good general purpose horse for farm work. Its color is bay, brown, or black. It has a longer neck and longer legs than the hackney. There are comparatively few representatives of the breed in America.

The French Coach is similar to the German coach horse. It has a long stride with good knee action. The French race tracks are $2\frac{1}{2}$ miles in length, and the horses are speeded on sod so as to develop the action most desired in a carriage horse. The colors vary, but are usually sorrel, black, bay, or brown.

The Cleveland Bay is bred in the county of York in England. It has not been considered much of a success in America. The breed is the largest of the coach horses. Although it is a good roadster, it does not have the fine action that other coach breeds possess. This breed is always bay in color with black legs. It may have a white star in the forehead.

The *families* are named from the stallions from which they originated.

NAME OF STALLION	HOME OF FAMILY	NAME OF FAMILY
Hambletonian 10	New York	Hambletonian
Henry Clay	Near Philadelphia	Clay
Justice Morgan	Vermont	Morgan
Pilot	Kentucky	Pilot
Tom Hal	Kentucky	Hal

The *pacers* and the *trotters* have the same origin. In fact, some trotters can pace well and some pacers have records as trotters. The fastest pacer in the world is Dan Patch, owned by Mr. M. W. Savage, Minneapolis. Dan Patch paced one mile in 1 minute and 55 seconds.

The *thoroughbred* is the name of a family of horses bred in England for racing under the saddle. The word is often improperly used instead of *pure bred*, which has reference to animals having a fixed type and certain characteristics which are registered by an association organized for the purpose of preserving and improving the breed.

Shetland ponies are a very small breed of horses originating in the Shetland Islands off the coast of Scotland. They are bred for their diminutive size. They are from 36 to 46 inches in height, are strong, of blocky build, and can be kept very economically. Their kind disposition makes them especially serviceable for children.

The *broncho* is a pony bred on the western plains in the United States. It is

FIG. 188. — Shetland Pony.

of uncertain origin, and since the introduction of large pure-bred stallions in the herds is much larger than formerly and varies greatly in character.
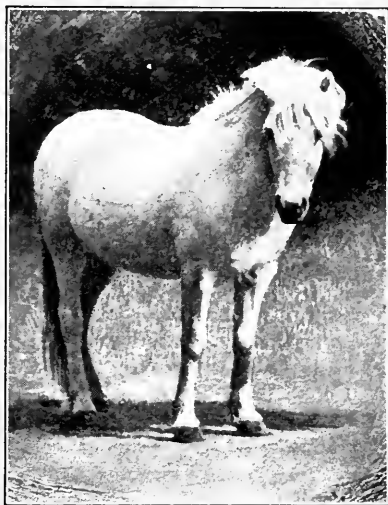
The Mule. — Mules are a cross between the jackass and the horse. The result of this cross is a hybrid that does not produce offspring. The mule is a patient, gentle animal of great strength and endurance. It will endure hard usage and a warm climate

better than a horse. It is used in the southern states more than in the northern. It is free from most animal diseases and remains serviceable even when quite old. The prevailing opinion that mules are treacherous and addicted to kicking is not borne out by the facts. St. Louis is the greatest market for mules in the world.
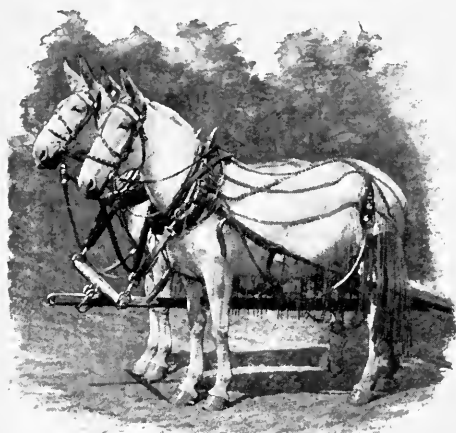
FIG. 189. — Mules.

Care of Horses. — It has been experimentally demonstrated that ruminating (cud-chewing) animals, like the cow and sheep, can digest a much larger percentage of fats and crude fiber than horses, and it has long been recognized that, in general, horses digest their food less thoroughly than cattle. This would seem to indicate that horses to be kept in good condition must be fed with care. (See Chapter VIII.) The object is not to fatten the horse, for that will unfit him for labor and thus render him useless. Provided a horse is in good condition, it is seldom desirable to increase his weight. The best test of suitable feeding rations for a horse is that the animal maintains an even weight.

It is necessary for the health of a horse that he be kept clean and that he be fed clean fodder. Clover

hay is too dusty for horses, timothy being much better.

Care should be taken that no part of the harness chafes the skin, or there may result sores that will be hard to heal. Very cold bits often tear the skin of the mouth and cause serious difficulty. Tight checking is cruel and unnecessary.

Training a Horse. — As a colt easily forms habits but never, or almost never, breaks one once formed, it is important to begin the training of a horse early and to devote care to it, if one wishes to rear a horse that is tractable and reliable. The training should begin with the trainer himself. If he cannot control himself, he can never train a horse successfully. Firmness, gentleness, steadiness, even temper, and self-control are necessary characteristics of a good horse trainer. Care should be taken to teach one command at a time, and that one always meaning the same thing, and never to give contradictory commands. "Whoa back" is a direction that no horse could obey. A horse should be trained to stand still during harnessing and loading; in short, to await the word of command to start, and to stand still after being stopped.

A horse that is trained in the few necessary words of command will show little need for the whip or the jerked lines.

SHEEP

Sheep may be raised on the farm for two purposes, mutton and wool. In America, until recent years, wool has been the prime consideration in raising sheep, and when the price of wool has been high, comparatively large profits have been made. But the growing demand for mutton has turned the attention of farm-

ers to the raising of sheep for this purpose, the fleece value being incidental, and this industry is fast assuming large proportions. It is thought by some that our rich lands and abundant feeds are well suited to the growth of mutton sheep, and that they, if properly selected, can grow a large part of the wool needed for manufacturing in this country; that is, that certain breeds are capable of development into *dual purpose* sheep.

Sheep can thrive on scanty pastures, and are especially valuable in cleaning out the weeds on a farm, but they are capable of making as large returns for good feeding as any other farm animal, except the hog. The production cost of a pound of mutton is no more than that of a pound of beef, and the wool gives additional value in later years. Farmers in the grain-producing states have been engaging in this industry with profitable returns.

Regularity and uniformity in feeding are of the first importance in raising good sheep, some authorities advocating two feedings daily, others three. Kind treatment, clean troughs, healthy quarters, pure water, and the use of salt and sulphur are requisites in keeping sheep in good condition. The best coarse fodders for winter feeding for sheep are clover hay, pea straw, and corn. During the summer, in regions where droughts are common, green fodder, such as rape or rye, should supplement the dry pasturage. Oats and bran are satisfactory grain foods for sheep.

Breeds of Sheep. — Sheep are divided into three classes according to the grade of wool they produce: (1) fine-wool producers, the Merinos; (2) medium-grade wool producers, the Southdown, the Shropshire,

the Oxford, the Dorset, and the Cheviot; (3) long-
wool producers, the Cotswold, the Leicester, and the
Lincoln.

The Merinos, native of Spain, are noted for their fine
wool. In Spain they are very small, but sheep-breeders
in this country have
produced a larger
type, numerous in
the southwestern
part of the United
States. This type
can be developed
to furnish good
mutton as well as
good wool. The
Delaine and Ram-
bouillet (French

Fig. 190. — Merino.

Merinos) are descended from the Merino, the second
producing good mutton. The medium-grade and long-
wool producers are natives of England, most of them
taking the name of the county where they predominate.
The Southdown and Shropshire are famous for their
mutton rather than for their wool. They are quite nu-
merous in the east and the Mississippi Valley. The
long-wooled sheep are not common in this country, the
Cotswold being the only one much known.

Notes. — The *Merinos* are distinguished by the large wrinkles on
their necks and bodies. The rams have horns, but the ewes are horn-
less. The mutton is not of very good quality and the lambs are late
in development. The breed has been greatly improved in the United
States and is here called the American Merino. Its chief value is in
its fine wool. It produces as high as 25 per cent of its weight in wool,
not being excelled by any other breed in this particular.

The *Delaines* are derived from the Merino by selection with a purpose to improve the mutton quality and to produce a Merino with fewer wrinkles, or folds, in the skin. They have succeeded in producing an animal fairly good for mutton and having a fleece that is second only to the Merino. The lambs are stronger and develop earlier than the Merino.

Fig. 191. — Delaine.

The *Rambouillet* has its native home in France. There, by selection from flocks originating from the Spanish Merino, a sheep of larger size has been produced. It does not differ materially in appearance from the Delaine. It has large folds on the neck and breast, but few or none on the body. It is the largest of the Merino family. It is covered with fleece all over the body, as are the other Merinos, but it is whiter than the others, owing to the fact that the wool is not so oily.

Fig. 192. — Rambouillet.

The *Southdown* originated in the southern counties of England, a low range of chalky cliffs, called the South Downs, giving the breed its name. This is a small sheep of distinct mutton quality. It has a short fleece. It is a superior feeder, maturing rapidly, and its mutton holds first place

Fig. 193. — Southdown.

in the best markets. Its face and legs are a reddish or grayish brown. Its disposition is quiet and docile.

The *Shropshire* originated in the counties of Shropshire and Stafford in England. It has some Southdown blood with some of the longer-wooled breeds. This is probably the most popular breed in

FIG. 194. — Shropshire.

America. It is of excellent mutton quality, of good size, and produces a fleece of medium length and weight. The Shropshire has a black face, ears and legs, and it is sometimes called the "black face." The lambs mature early and the ewes often give birth to twins.

The *Hampshire*, bred
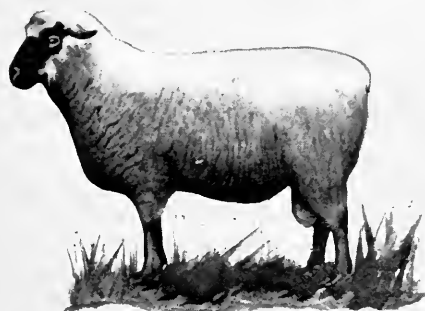
FIG. 195. — Hampshire.

in the county of Hampshire, England, resembles the Shropshire, but is larger and coarser. It does not produce so much wool and the quality is not so good. The face is not covered with so much wool as the Shropshire, and the color of the legs, face, and ears is a dark brown.

The *Oxford* is the largest of the middle-wooled

FIG. 196. — Oxford.

breed.   It produces a heavy fleece of coarse wool and its mutton is of good quality.   In appearance it resembles the Shropshire.   It is hornless, has dark brown face and legs, and is wooled over the forehead.

FIG. 197. — Horned Dorset.

On account of its docile disposition, good mutton-producing quality, heavy fleece, and large size, the Oxford is growing in popularity with the American farmer.

The *Horned Dorset* is another English breed. It is especially valuable for producing early spring lambs.   Both males and females have horns.   The horns of the males curve backward and spirally ; those of the female curve outward, down, and forward.   The face, legs, and hoofs are white.

The *Cheviot*, bred in the Cheviot Hills between England and Scotland, is a sheep about the size of the Shropshire.   The head is hornless and is covered with short white hair.   The fleece comes up the neck to behind the ears, forming a kind of collar.   The lower legs are white and the hoofs are black. The breed is valu-

FIG. 198. — Cheviot.

able as a grazer, obtaining a good living from pastures that would not support other sheep.
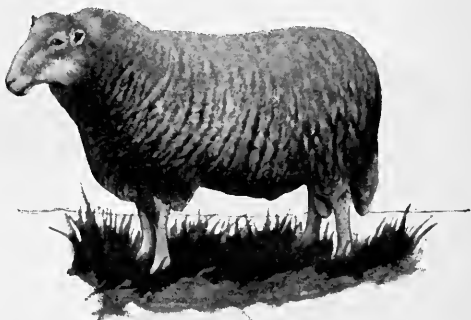
The *Cotswold* is one of the long-wooled sheep.   It is bred in the county of Gloucester, England.   It has a long, curly fleece, parting

along the back and hanging down the sides to a considerable length.
The head is hornless and usually white. It has curls of fleece extend-
ing from the forehead down over the nose. This is one of the largest
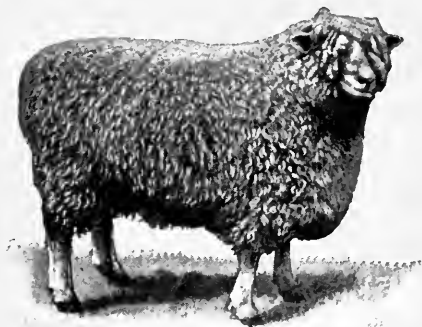
FIG. 199. — Cotswold.

sheep in existence. It stands confinement well, but does not thrive
well on scant pastures.

The *Lincoln* has its native home in the county of Lincoln, Eng-
land. It is probably the largest sheep, weighing from 300 to 400 pounds.
It has long, spiral, curly locks of coarse wool. This parts along the
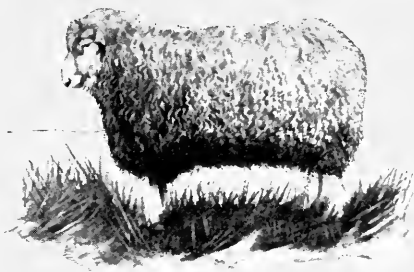
FIG. 200. — Lincoln.

back and hangs down the sides. This breed furnishes the longest
fleece of any, some samples being 21 inches in length. The head and
legs are white. The forehead has tufts of wool, making a foretop not
so long as the Cotswold.

The *Leicester* (pronounced *lester*) was originated in the county of the same name in England. The wool lies in close spirals over the body, but is not so long as that of the other long-wooled breeds. The
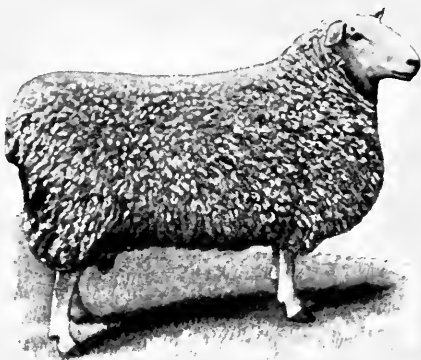
FIG. 201. — Leicester.

head and lower legs are white and have no wool. The wool is not heavy and it does not produce good mutton. There are very few of these sheep in America.

SWINE

The hog, in spite of its unattractive exterior, is an important economic factor in the United States, for we are known as a nation of pork eaters and pork producers. The dairy belt and corn belt are always thought of as the hog belt also, for corn and skimmed milk are considered the great pork producers. That these are not the only foods suitable for this purpose and that the hog belt may easily extend far beyond the corn belt and the dairy belt has been clearly shown, for any locality that will grow clover, peas, beans, barley, wheat, oats, or rye can raise hogs profitably. The famous Danish bacon, so popular in English markets, comes from pigs fed on barley and dairy by-prod-

ucts. In localities where corn raising is not possible, barley may well be substituted for feeding pigs, with a gain in the quality of the bacon produced.

Hogs do not thrive unless well protected from weather extremes. A clean inclosure with sleeping pens under cover and feeding pens adjoining is essential. Light, ventilation, warmth, and cleanliness are as necessary to successful raising of pigs as any other farm animal. Low, wide, shallow iron troughs are advised for feeding purposes, iron being regarded as more sanitary than wood.

Types of Hogs. — There are two different types of hogs, the lard type and the bacon type. The lard type of hogs is grown chiefly in the corn belt of the United States, where corn is the principal food for fattening. They are large, fat hogs, averaging as marketed about 220 pounds. The fat is accumulated in large masses under the skin and about the kidneys. The fat about the kidneys makes what is called *leaf lard*.

The lard hog has a compact, thick body, short head, broad back, strong hams, deep body, and short legs. The disposition of the fat type of hogs is usually quiet, and as the animal becomes very fat it becomes sluggish, spending much of its time in sleep. The Poland China, the Berkshire, the Chester White, and the Duroc Jersey are the principal breeds of the fat hogs.

The bacon type is used in producing the pieces of side meat with lean and fat in streaks. This makes the high-priced bacon that is relished by so many. The bacon type of hogs is grown in Canada and in other parts of the world where other foods than corn are used for fattening and finishing for market. The bacon hog is a long-bodied animal, much narrower than the lard

hog. Its side is long and wide, making the largest amount possible of side meat. The hams are smaller and the head and neck are longer than in the lard type of hogs.

The principal bacon breeds are the Large Yorkshire, the Tamworth, and the Thin Rind, or Hampshire.

Hog Cholera. — Hog cholera has been one of the greatest hindrances in raising hogs. It is a contagious disease of a virulent type. The germs of this disease are carried from one herd to another on the shoes of visitors, on the feet of dogs or other animals, and by streams of water. Improper feeding makes hogs especially susceptible to this disease. It is quite certain that the disease can be controlled and probably wiped out by the use of a recently discovered treatment of vaccination. The various Experiment Stations in the United States are furnishing the vaccine and giving full directions as to its use.

Notes. — Lard Type Hogs. The *Poland China* is probably the most typical hog of the lard type. It is the most numerous in the corn-growing states. It originated in southwestern Ohio. There is no good reason for the name of the breed. For several years breeders of this hog have been selecting for early maturity and quick-fattening qualities. In these particulars the breed

Fig. 202. — Poland China.

excels. It is also very good in the hams. It has short legs, a very broad and curved back, a straight nose, and the top third of the ear breaks over into a droop. The color of the Poland China is usually

black with white in the face, on the tail, and on the feet. It may have spots of white on the body.

The *Berkshire* derives its name from the locality in which it originated, namely, Berkshire, England. It is a very popular breed in the United States. Its breeders claim for it large size, early maturing quality, and the production of large litters. The lean of its flesh is well mixed with the fat and if fed properly may produce bacon of good quality. The Berk-
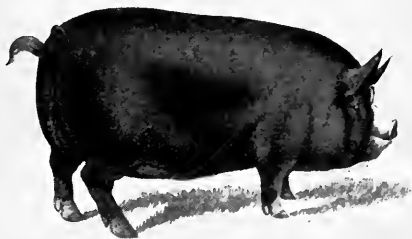
FIG. 203. — Berkshire.

shire is easily distinguished from the Poland China by having an erect instead of a drooping ear and by having an upturned snout. Its color is black with "six white points," four white feet, white in the face, and white on the tail.

The *Chester Whites* originated in Chester County, Pennsylvania. They are an older breed than the Poland China and considerably larger and coarser. This hog is not quite so early maturing, but is a profitable breed, as it makes large gains from the food consumed. An improved variety of this breed, originated in Ohio, is called the Ohio Improved Chester Whites (O. I. C.).
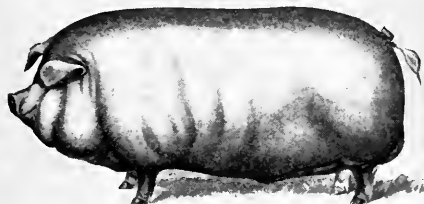
FIG. 204. — Chester White.

This variety is not so coarse or so large as the regular breed. The Chester Whites are white in color, but may have dark spots on the skin under the hair. They have broad backs, deep bodies, and large, drooping ears.

The *Duroc Jersey* is one of the most recent of the American

breeds of swine. It is rapidly growing in favor on account of the

FIG. 205. — Duroc Jersey.

large litters which it produces. Its qualities are very similar to those of the Poland China. The color is always red, but may vary in shades. The ears droop forward.

Other breeds that are recent or not so well established in America are the Cheshire, the Victoria, the Essex, the small Yorkshire, and the Suffolk.

The Bacon Type Hogs. The *Large Yorkshire* originated in York, England. This is the most popular bacon breed. It is especially prized in Canada. Their bodies are very long and very deep. They never become very fat, yet they weigh as much as the

FIG. 206. — Yorkshire.

heaviest fat hogs. They do not mature very early, but they furnish an excellent quality of pork. In England a higher price is paid for pork
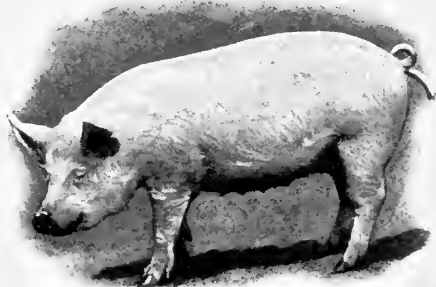
FIG. 207. — Tamworth.

from the bacon hogs, but no distinction in favor of hogs of this type, as yet, is made in the United States. The Yorkshire is white all over and has a pink skin.

The *Tamworth* also originated in England. This breed is noted
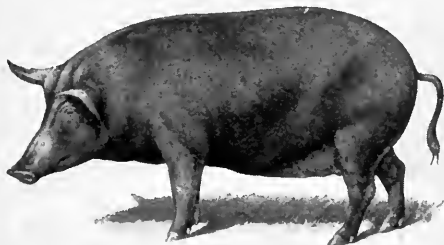
for its depth of body, producing a large quantity of bacon. It is difficult to fatten, but produces very large litters of pigs. The legs are long, the color is red, and the head and snout are long.

The *Thin Rind* or *Hampshire* probably originated in England. It is about the medium size and is especially adapted to foraging for food in field and forest. It is not very widely distributed in America.

FIG. 208. — Thin Rind.

The color is usually black with a white belt about the body just back of the forelegs, which are also usually white.
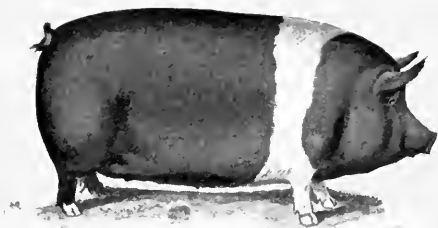
POULTRY

Domestic fowls have a wide distribution throughout the United States, but poultry raising as an industry is not so widespread. Most farmers raise chickens, ducks, turkeys, and geese merely as a means of supplying their own tables with an economical and palatable food. Incidentally, they market a few in neighboring towns, when they have an oversupply or the price is high. Yet the aggregate poultry product in the United States has a value exceeded only by corn, dairy products, beef cattle, cotton, swine, and wheat.

" The farmer's hen is becoming a worthy companion to his cow. The annual production of eggs is now a score of billions, and, after supplying the needs of factories, tanneries, bakeries, and other trades, they are becoming a substitute for high-priced meats, besides entering more generally into the everyday food of the people. Poultry products have now climbed to a place

of more than half a billion dollars in value; and so the farmer's hen competes with wheat for precedence." [1]

Most farmers raise some ducks, geese, or turkeys, and often all three with their chickens. Ducks are good foragers, eating the refuse of food rejected by other fowls. Turkeys are raised for their meat rather than for eggs, their flesh bringing a higher price in the market than that of any other fowl. They are distinctively an American fowl, being derived from our wild turkey.

Like most other farm stock, poultry serve a double purpose, being either meat producers or egg producers, some breeds being best for the one purpose and some for the other, while still other breeds answer very well as dual purpose hens

Incubators, or artificial hatchers, have replaced the hen where it is desired to rear fowls in large numbers for the production of eggs, or when early hatching is desired. The Mediterranean fowls cannot be depended upon for natural incubation where large numbers are to be raised. Expert poultry men, by great care, close observation, and good judgment have, for a term of years hatched in incubators over four fifths of all eggs put into the machine.

Housing of Poultry. — Poultry should be so cared for the year round that the nearest possible approach to ideal conditions may prevail. The house should be built on dry, well-drained ground, having an east and west extension and openings toward the south so that it may have the full benefit of sunshine all the year. The perches, made of 2 by 3 inch scantling, should have a slightly rounded surface on the upper side and be free from cracks or blemishes, so that vermin may not find

[1] Yearbook, 1905.

convenient hiding places. It is essential in the construction of the poultry house that all the furnishings should be movable, so that they may be taken out and cleaned frequently. A platform made to catch the droppings may be conveniently placed under the perches and the nests made under this. The floor of the house should be dry and tight, but ventilated underneath. Wood is better for floors than cement or earth, being drier and warmer. The amount of space required by each fowl depends upon whether there is a shed attached to the house or whether the fowls have free access to the open fields. If either of the latter conditions prevails, about 5 square feet of surface for each fowl is sufficient, but in the former case, double the space should be provided. Good ventilation is necessary, but draughts are injurious to hens.

Diseases. — Poultry are subject to many diseases, such as gapes, caused by worms in the windpipe; cholera, a germ disease, therefore contagious; roup, sometimes called the winter disease. Lice afflict poultry, frequently breeding on their bodies, and mites, which suck their blood, often infest the walls, roosts, and nests. Cleanliness is one of the surest preventives of both disease and vermin.

Breeds of Fowls. — Fowls are variously classified, — according to their tendency to produce flesh or eggs, according to their tendency to become broody, and according to their origin geographically.

The most useful classification is the first one mentioned, the tendency to produce a meat or an egg product. This gives four classes of fowls: the *egg breeds*, those that are kept primarily for egg production; the *meat breeds*, those that are kept principally for their

production of flesh; the *general purpose* breeds, those that are fair in both egg and meat production; the *fancy breeds*, which are kept for some oddity of color, form, or size.

The Egg Breeds are usually poor sitters, the hens not becoming broody till they are at least two years old. They are of a very nervous disposition. They have a tendency to fly on slight provocation and are not adapted to close confinement. Many of these breeds give good results when confined in small yards or runs, but this life is contrary to the nature of the egg breeds, which are adapted to a large range and to seeking their own food. Their bodies are small and trim, having the feathers laid close to the body. Most of the breeds of this class originated in countries or islands of the Mediterranean Sea, and they are therefore called the Mediterranean breeds. They are better adapted to warm than to very cold climates. They have large combs and wattles; when these are frozen, egg production stops for a time. The principal egg breeds are the Leghorns, Minorcas, Spanish, and Hamburgs.

The Meat Breeds, although producing some eggs, are kept for their ability to grow a large body with a good supply of meat. They are classed as sitters, becoming broody early and persisting in sitting. They are of a phlegmatic disposition and are easily handled. They bear confinement well and are too inactive to forage for their food. On that account, they should be supplied with their food.

They grow a large quantity of feathers which stand out from the body, giving a fluffy appearance and making these fowl adapted to stand the rigors of a cold climate. They originated in Asia, and are therefore

called the Asiatics. The principal representatives of this class are the Brahmas, Cochins, and Langshans.

The General Purpose Breeds. — This class of fowls occupies a middle ground between the egg breeds and the meat breeds. The bodies are medium in size. The hens become broody and make good mothers. They produce more eggs than the meat breeds and do not break so many of the eggs in sitting as the clumsier and heavier hens. They are gentle and easily handled. They do well in confinement and make good use of a large range if they are allowed the privilege. They produce a fair number of eggs in a year and their bodies furnish a good quantity of flesh of good quality. These breeds are easily adapted to varying conditions and have been bred towards egg production, making "laying strains" that are excellent for this purpose. They have also been increased in size till in weight they equal many of the meat breeds. The principal general purpose breeds are the Plymouth Rocks, Wyandottes, Rhode Island Reds, and the Orpingtons.

Egg Breeds Described. — *Leghorn* (White, Single and Rose Comb White, Silver Duckwing, Brown, Dominique, Black, Rose Comb Brown, and Buff). The name of this breed was probably derived from the city of Leghorn, Italy, from which place they are supposed to have been brought to America. This is the typical egg breed. All va-

FIG. 209. — Rose Comb Brown Leghorns.

rieties are comparatively small and are so active that it is difficult to fatten them. They are persistent layers

of rather large, white eggs. They begin to lay at the age of five months and continue for five years. The young become feathered and develop early in life, as a breed showing great hardiness.

FIG. 210. — Rose Comb Black Minorcas.

Minorca (Black, Rose Comb Black, White, and Rose Comb White). This breed, the heaviest of the Mediterranean fowls, originated on the island of Minorca in the Mediterranean Sea. They are great egg producers. They lay a very large, pure white egg that is quite popular in most markets. The flesh is good for meat, but as most people prefer fowls having a yellow skin and shanks, instead of the white skin and dark shanks and feet of the Minorca, they are not in favor for their meat. They have the general characteristics of the Leghorn and possess a strong constitution and great vigor.

Spanish. These are now called the White-faced Black Spanish. As the name indicates, they probably came from Spain, being one of the oldest fowls of which we have any record. This breed is glossy greenish black with black shanks and toes, the face and ear lobes being white.
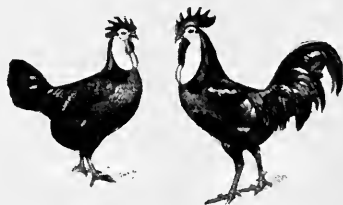
FIG. 211. — White-faced Black Spanish.

The legs are somewhat longer than other breeds described. They do not show the hardiness nor vigor of the other breeds.

Hamburg (Silver Spangled, Golden Spangled, Golden Penciled, White, and Black). This is a breed of small, active birds. Being great fliers, they require a large range. They are prolific layers of small white eggs.

All varieties have dark-colored shanks and toes, and rose combs which terminate in a spike or point at the rear.

FIG. 212.— Silver Spangled Hamburgs.

The Hamburgs originated in northern Germany or Holland. The *Red Caps* resemble the Hamburgs, but are larger, with a black and red plumage.

The Andalusians. This breed is thought to have its origin in the province of Andalusia in southern Spain. The feathers are a bluish gray or dove color. The shanks and toes are a slaty blue. They are excellent layers, and resemble the Leghorn closely except in color.

Meat Breeds Described. — *Brahmas* (Light and Dark). This typical meat breed probably descended from the fowls of India. The young mature somewhat slowly. So inactive are the Brahmas that a fence four feet high will restrain them. They have heavy bodies, weighing
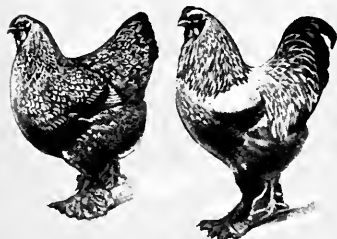
FIG. 213.— Dark Brahmas.

from nine to twelve pounds. They are persistent sitters, but so clumsy that they are liable to break their eggs. The flesh is of good quality, but with

a tendency to coarseness. They lay a fair number of eggs, brown in color. The skin of the legs and shanks is yellow and the outsides of the shanks and toes are feathered. One distinguishing point of this breed is the pea comb. This comb appears to be made by the union of three single combs with cross serrations,
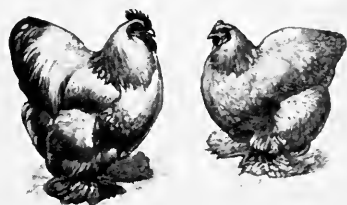
FIG. 214. — Buff Cochins.

the middle comb standing higher than the other two.

Cochins (Buff Partridge, Black, and White). This breed was introduced from China. They are slightly lighter in weight than the Brahmas. They are fairly good layers, good sitters and fatten very easily. They have an abundance of fluffy feathers and stand confinement well.

Langshans (Black and White). This breed is from northern China. They are smaller and more active than any of the other Asiatics.

Their flesh is of excellent quality. They have white skin and dark shanks, with less abundant leg feathering than the others. These fowls have long bodies and

FIG. 215. — Black Langshans.

carry the tail high, almost on a level with the comb.

Faverolle. This can hardly be considered a distinct breed. It is a cross among the Brahmas, Cochins, Dorkings, and Houdans. The breed is somewhat nu-

merous in France, but has not gained much of a standing in this country.

General Purpose Breeds Described. *Plymouth Rock* (Barred, White, Buff, Partridge, and Silver Penciled). This most useful breed is of American origin, originating in Massachusetts. It approaches the meat breeds for size, having rather long, broad, and deep bodies, and the egg breeds for laying, being above the average as winter layers, and the hens make excellent mothers. The White

FIG. 216. — Barred Plymouth Rocks.

Rocks have a disadvantage in appearance when dressed for market. There are always some undeveloped feathers under the skin. If these are dark, they must be removed, which produces a discoloration of the skin. All varieties have medium-sized, single combs.

Wyandotte (White, Silver Laced, Golden, Buff, Black, Partridge, and Silver Penciled). This breed was de-

FIG. 217. — Silver Laced Wyandottes.

veloped later than the Plymouth Rocks. By many it is considered equal if not superior to the Plymouth Rock as a general purpose fowl. Its body, somewhat smaller than the Plymouth Rocks, is short, deep, and round, yielding a flesh that is tender and juicy, with a relatively small proportion of bone. Its low rose comb makes it a breed well suited to a cold climate. These fowls are good layers of fair-sized eggs, brown in color.

Rhode Island Red (Rose Comb and Single Comb). This breed was made by crossing all known varieties
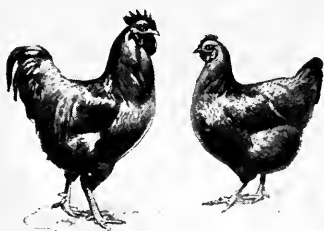
FIG. 218. — Single Comb Rhode Island Reds.

of fowls and making selection for a good general purpose fowl. In shape it resembles the Plymouth Rock somewhat, having broad, deep bodies of long length. They carry a large proportion of meat on their well-formed bodies. The plumage is a rich red above and a lighter shade of red underneath the body. The main tail feathers are black.

Orpington (White, Black, Buff, Jubilee, and Single and Rose Comb of each variety). The Orpingtons are a new breed of general purpose fowls that has become very popular in America. Although originated in England, many improved strains have been bred in this country. The Orpingtons are a large-sized, compactly built fowl, broad and deep, with a fair length of back and body. The carcass of the Orpington is noted for its plumpness and full-

FIG. 219. — White Orpingtons.

ness of breast. The White Orpingtons are an especially good laying variety of this breed.

Java (Black and Mottled). This breed originated somewhere in the United States. The Javas have a body of greater length than either the Plymouth

Rocks or the Rhode Island Reds. They have single combs. The face, ear lobes, and wattles are bright red.

Dominique. These fowl resemble in feathering the barred Plymouth Rocks, having blue barred feathers and a rose comb, but in form they are more like the Hamburg. They are medium in all particulars

FIG. 220. — Mottled Javas.

as compared with other general purpose breeds. The

FIG. 221. — American Dominiques.

Black Java was crossed with this fowl in the making of the Plymouth Rock.

Dorking (White, Silver, Gray, and Colored). The Dorking, of English origin, is one of the oldest breeds in existence. This breed

is characterized by having very long, broad, deep, and full bodies, low set on the legs. The White Dorkings have a rose comb; the other varieties have the single comb. The Dorkings have five toes.

Houdan. This is the most popular of the French

FIG. 222. — Colored Dorkings.

breeds. They produce large, white-shelled eggs, are quick to develop, and make a very acceptable table fowl. They possess a large crest of feathers which covers the head and interferes with their sight of ob-

jects about them or in the air. With a body much

FIG. 223. — Houdans.

like the Orpington they are built for egg and for meat production. The comb is V-shaped and of small size. The feet have five toes and the plumage is black, the ends of the feathers being tipped with white.
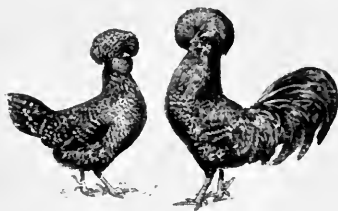
Cornish Indian (Dark and White). This is a close-feathered, muscular bird which weighs more than the apparent size would indicate. It is a good general purpose breed, noted for the rich flavor known only to this breed.
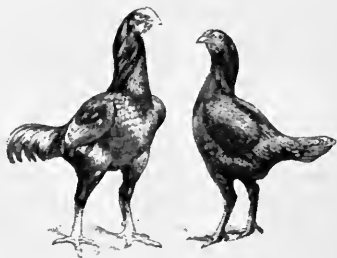
FIG. 224. — Cornish Indians.

Fancy Breeds. — The fancy breeds are not adapted to practical purposes and can hardly be classed as farm breeds. The most common of the fancy breeds are the Polish, Game, Silky, Sultan, Frizzle, Rumpless, and Bantams of several varieties. These fowls are not bred either for egg or for meat production. They are difficult to breed true to color and shape, requiring therefore special attention. The Bantams are often kept as pets, but they should not be allowed to mingle with the other fowl.

Ducks. — All varieties of ducks, except the Muscovy, have descended from the Mallard, a wild duck. The original white duck is probably the Aylesbury. A large business has sprung up in this country in furnish-

ing young ducks for the market. If ducks can be marketed when they are 10 to 12 weeks old, there is much profit in the business. If sufficient water is furnished them for drinking, they thrive well without swimming pools.

Breeds of Ducks. — *Pekin.* This is the most popular and profitable of all the breeds. It is pure white, hardy, and an excellent layer. Ducks ten weeks old may be fattened to five pounds weight for marketing. The shape is

FIG. 225. — Pekin Ducks.

rather upright, the rear of the body flat, the back straight, and the breast very full. These ducks originated in China, but have been wonderfully developed in America.

Aylesbury. This heavier but not so prolific breed

FIG. 226. — Rouen Ducks.

is preferred by some to the Pekin. It was developed in England.
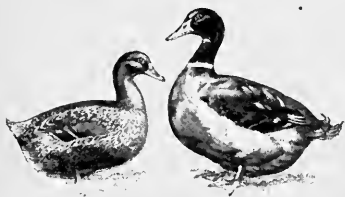
The *Rouen* was also developed in England, though it originated in France. It compares favorably with the Pekin and produces fine winter roasters. The color is nearly the same as the wild Mallard.

The *Black Cayuga* is an American bird. It has characteristics similar to the Pekin, only smaller, but the black color lowers its marketing value.

Indian Runner. Because of its egg production
this breed is termed the
Leghorn of the duck family
and has become very pop-
ular. It is the smallest of
the breeds here described.
It is of almost erect car-
riage and has a long neck.
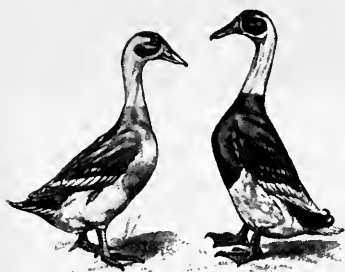
FIG. 227. — Indian Runners.

Muscovy. — This breed
probably originated in
Peru. It is not allied to
the other breeds in any way. The large head of the
drake is covered with a
rough, caruncled red skin
somewhat similar to that
of a turkey gobbler. The
drakes are disposed to be
quite pugnacious. The
female, much smaller

FIG. 228. — Colored Muscovies.

than the male, sits well and makes a good mother.
For flavor the Muscovy cannot be equalled.

Geese. — There is now a growing market for geese
to be used as a large table fowl in place of the turkey
and also for younger and daintier small roasters. Geese
are good grazers, therefore where pastures are abundant
little other food need be given them during the grass
season. The goslings are hardy and but little affected
by disease. Some profit is made by plucking the feathers
from the breast of live geese and selling them to make
pillows, for these feathers bring the highest price in the
market.

Breeds of Geese. — *Toulouse.* These are large-
framed birds, sometimes weighing 30 pounds each. They

are good layers and usually are good sitters. Quiet and peaceable, they bear confinement well. The Toulouse is gray in color and has a loose fold of skin in aged fowls that makes a pouch which hangs down between the legs almost touching the ground.

Embden. The Embden geese are pure white, resembling the Toulouse in form, but have no pouch. They lay fewer eggs, but are better sitters. The goslings develop early and in 10 weeks may be fattened to from 8 to 10 pounds weight.

FIG. 229. — Toulouse Geese.

The *Africans* are especially good as table fowls. Their flesh is not so coarse as that of other geese. They are good layers and the young grow very rapidly.

Chinese. Geese of this class may be considered as the "Bantams" of the goose family, for they are much smaller than other breeds. They
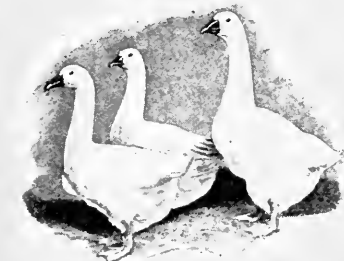
FIG. 230. — Embden Geese.

are not a profitable goose on the farm.

FIG. 231. — African Geese.

Turkeys. America is the natural home of the turkey. Our domesticated varieties have sprung from the wild turkey and still retain many of the characteristics of their wild progenitors. The wild turkey is

still found in the large woods of many states in the eastern part of the United States. Not thriving well in confinement, they must have a wide range for the best results. They cannot be raised in large flocks together. If they can find their own nests in a brush heap in the woods and raise their young in a natural way, as the wild turkey does, they are healthier and

the results are better. The young, called poults, are at first very tender and liable to chill, but as soon as they are feathered they become quite hardy.

Breeds of Domestic Turkeys. — *Bronze.* This is the largest breed, the adult male weighing about 36 pounds and the female 20 pounds when raised under favorable conditions. They have a roving disposition, many times being found over a mile

FIG. 232. — Bronze Turkeys.

from their home. Because of its size this is the most popular breed.

Narragansett. This breed takes its name from the bay by that name in Rhode Island, where turkeys are bred in large numbers. These turkeys, gray in color, do not roam so far as the Bronze turkey.

White Holland. This turkey is increasing in popularity because of its

FIG. 233. — Narragansett Turkeys.

good laying qualities and the fact that it is not inclined to roam so far as other turkeys. It is not so

heavy as the Bronze turkey. As its name indicates, it has a white plumage.

Buff turkey and *Slate turkey* are two varieties that are between the Bronze and the White Holland turkey in size. They are not bred in great numbers.

The *Black turkey* has been bred for years in England, but there are very few representatives of this breed in America.

Bourbon Red turkeys were originated in Kentucky. They compare both in size and other characteristics with the mammoth Bronze, the only difference being that they are red instead of bronze.

FIG. 234. — White Holland Turkeys.

CHAPTER VIII

FEEDS AND FEEDING

Water and Dry Matter. — An analysis of any food stuff will show, first, that it is composed of water and dry matter. The proportion of each may be determined by weighing the substance, then heating it till all the water is driven off and then weighing it again. A surprising amount of water will be found in all foods. This water, although it increases the palatability of the food, might be taken as a drink just as well, for the dry matter contains the substances that furnish the animal products and growth.

If now the dry matter in foods is burned, it will be found that after all the food that can be burned is consumed there still remains a substance called ash.

Ash. — This residue contains the incombustible portion of the dry matter. The ash is an essential in the food of all animals. It enters into the composition of the bones and is found in all other parts of the body. Foods ordinarily contain a large enough proportion of mineral matter to furnish the body with all that it needs, but sometimes it is necessary to supply it directly to animals. Hens are fed lime, ground oyster shells, and ground bone to supply this lack in their food. Hogs are fed bone meal, ashes, and even floats to give enough ash to fulfill all the demands of the body. Salt is furnished for the same purpose to cattle, horses, and sheep.

Three Great Classes. — The part of the food that is consumed by burning is the part called organic matter. The organic components of feeding stuffs fall into three classes, Proteins, Carbohydrates, and Fats.

The chief consideration in feeding is to obtain, in the correct proportions and with the greatest economy, a supply of each of these classes of foods adequate to build up the body and to furnish the animal products desired.

Note. — Dry hay contains from 10 per cent to 20 per cent of water. The grains contain about 10 per cent and silage contains as high as 80 per cent of water.

Protein. — The chief function of the protein in food is to form lean tissue. It also is one of the most important parts of milk and of eggs. Protein contains other elements (see page 26), but the most important is nitrogen; on this account the protein part of food is called *nitrogenous*. This is the most expensive constituent of feeding stuffs. Foods for stock containing a large proportion of digestible protein are sold on the market at a relatively higher price than any others.

Carbohydrates. — The chief functions of carbohydrates are to furnish energy and to form fat. The largest part of the dry matter of most foods as eaten is carbohydrates. It is the cheapest part of food for animals. There are two classes of carbohydrates found in plants; namely, *fiber* and *nitrogen-free extract*. The fiber is the hard woody framework of the plant and the coarser bran of grains. It is of very little food value because of its nondigestibility. Nitrogen-free extract includes the more easily digested carbohydrates, the starches, sugars, and gums. It is called nitrogen-

free extract because it contains no nitrogen. The carbohydrates are all formed from CO_2 in the air with varying proportions of H_2O. (See page 34.)

Fat or Ether Extract. — The fats have the same functions as the carbohydrates — furnishing to animals in a condensed form energy and fat. It is because of the fact that fats are two and one fourth times as strong, pound for pound, in producing heat as other carbohydrates, that they are considered separately in feeding. In the carbohydrates the carbon is combined with hydrogen and oxygen in proportion to form water, whereas the carbon in fats is not so combined.

The term ether extract is a little more accurate than fats. In the tables compiled the fats not only include what are known as fats, but all the dry matter that can be dissolved out by ether. (See page 34.) Besides fat they include wax and chlorophyll.

Digestibility. — Not all the food elements in a food stuff are available for the use of the animal. Much depends upon the digestibility of the food. The digestibility of the food itself varies according to the time it is harvested; hay, for instance, should be cut and cured just before its seeds have ripened, while grain should be harvested when it is ripe.

Digestibility varies with different classes of animals. Cattle and sheep will digest a larger percentage of roughage than horses or pigs. It varies slightly also with different animals of the same class, depending on the age and on the individual peculiarities. Some animals are easy keepers, because they digest and assimilate a relatively larger proportion of the food that they eat than others.

It is evident that feeds of animals cannot be determined by rule. For the best results, the judgment of the feeder guided by rules should be used in feeding each animal.

Note. — The expression in percentage showing what part of a food element is digestible is called the coefficient of digestibility. If we know the weight of protein, for instance, in a given food, we may find the amount available for any class of animals by multiplying this weight by the coefficient of digestibility.

Feeding for Maintenance. — Scientists have determined quite accurately just the amount of food required to keep an animal in normal condition without increasing or decreasing in weight and without giving any product or labor. This is called a ration for maintenance. For instance, it has been determined that the average dairy cow, for each 100 pounds of her weight, requires for her maintenance under normal conditions each day:

Protein	.07 lb.
Carbohydrates	.7 lb.
Ether extract, or fat	.01 lb.

Other classes of animals require other proportions for maintenance. The maintenance ration is required for keeping up the body so that it may be in condition to give work or product, much as coal must be consumed under the boiler to warm the water before steam for work is formed.

Ration for Product. — After the animal has its maintenance ration, the additional food that is given may result in some valuable product. That may be increased growth, fat, milk, wool, eggs, or performance of work.

It is extra food given after the maintenance ration has been served that gives the products for which the animal is kept. The profits in feeding come only from feeding a ration in addition to the maintenance ration.

FULL RATION

RATION FOR MAINTENANCE	RATION FOR PRODUCT

THREE–FOURTHS RATION

RATION FOR MAINTENANCE	RATION FOR AVAILABLE PRODUCT

HALF RATION

RATION FOR MAINTENANCE	NOTHING FOR PRODUCT

From the above diagrams it is observed that a full ration will give the maximum product and, if the ration above the maintenance costs less than the product produced, the maximum profit. If three fourths of a full ration is fed, the product is cut in half, and if one-half ration is fed, there is nothing left for the product or profit. Liberal feeding is the only profitable feeding.

It may be that the cow, for instance, fed on half of a full ration may produce some milk, but she must do

it by drawing on the reserves in the form of flesh or fat in her body, with a consequent loss of weight.

Scientific Feeding. — Scientific feeding of farm animals consists, first, in knowing the composition of the body of the animal to be fed, and giving the animal such food as shall contain the elements required to maintain the body tissues and in such quantities and proportions as careful experiment may determine will keep the animal without loss or gain of weight. Second, the composition and weight of product that the animal gives should be known and an additional amount of food containing the elements found in the product should be fed in proper proportions and in quantity sufficient to make up the weight of the product.

Compounding Rations. — In making rations for different classes of farm animals such a combination of foods should be made as will fulfill the following conditions :

First, the food should be in accord with the physical character of the animals to be fed. Garbage should not be fed to horses, neither should timothy hay be fed to hogs.

Second, cattle, horses, and sheep should be fed a combination of roughage, such as hay, fodder, and silage, to give bulk to the ration, and some concentrates, such as grains, linseed meal, and cottonseed meal.

Third, such feeds should be chosen for a ration as will furnish the food elements necessary for the animal at the smallest cost. This will usually lead the farmer to feed only the products of his farm. It may in some cases, however, be more economical for him to sell certain products of the farm and to buy other feeds for his stock.

Fourth, the ration should be so compounded that the ratio between the protein and the carbohydrate and fat shall be such as the investigations of scientists have found to be the best for the purpose for which the animal is fed. This ratio is called the *nutritive ratio* and may be found for each class of animals, in the Appendix. A ration so compounded is called a *balanced ration*.

Notes. — The nutritive ratio best adapted to any animal or the nutritive ratio for any feed is obtained by comparing the amount of protein as given in the table with the amount of carbohydrates and fats, after the fats have been changed to the carbohydrate basis by multiplying them by $2\frac{1}{4}$.

One pound of cowpea silage is found to contain .015 pound protein, .086 pound carbohydrate, and .009 pound fat. Now, if the weight of fat is multiplied by 2.25, and added to .086, the weight of the carbohydrate, the sum is .106. .106 divided by .015 = 7. There is 7 times as much carbohydrate as protein. This may be represented in the form of a proportion as follows:

carbohydrate and fat : protein : : 1 : 7.

A *wide* nutritive ratio is one that has a large proportion of carbohydrates and fats compared with the protein. If the carbohydrates and fats are more than 8 to 1 as compared with protein, the ratio is said to be wide. If the ratio be less than 5.5 : 1, it is said to be *narrow*. A ratio between a wide and a narrow one is said to be a medium nutritive ratio. 14 : 1 is a wide nutritive ratio, 7 : 1 is a medium ratio, and 3 : 1 is a narrow ratio.

From the table in the Appendix make a list of eight feeds that are concentrates that have a narrow nutritive ratio. Make a similar list of four forms of *roughage* that have a narrow nutritive ratio. From the same table make a list of five feeds that have a wide nutritive ratio. Make a similar list of six roughages that have a wide nutritive ratio.

Note. — For the dairy cow such a basis for feeding has been made by Professor T. L. Haecker of the Minnesota Experiment Station.

His tables for feeding of dairy cows are given in a bulletin of the Minnesota Experiment Station. For other farm animals it has been more difficult to calculate the analysis and weight of the product in a practical way, but scientists are at work on the problem. Till such data are available, feeders should feed balanced rations in accord with the tables given in the Appendix, which are largely the results of experiments in feeding made in Germany.

Feeding Dairy Stock. — *Pasturage.* In the spring and summer pasturage is the chief resource in feeding dairy cows. It is during the months when the pasturage is good that cows give most abundant supplies of milk at the lowest cost. June butter is considered to be the best butter also, because of the flavor given it by the pastures.

When pasturage is abundant it is not necessary to give cows that are dry or are giving a moderate amount of milk any additional food, but producers of a large quantity of milk may be given some grain to furnish the protein given in the milk.

Soiling Crops. — In the late summer and fall when pastures are short, stock should be fed some green fodder. The feeding of green fodders is called *soiling*. Corn is most frequently fed for this purpose. Very often farmers prepare a corn field or a sorghum field near the barnyard or pasture to be used as a soiling crop. The seed is sown or planted thick in the rows. A large amount of green stuff may be raised in this way on a small plot of ground. In the southwestern states Kaffir corn is used extensively as a soiling crop.

If summer silage is available, it will be found more economical for feeding than growing soiling crops.

Winter Feeding. — The succulence of pasturage and of soiling may be made up in a measure by feeding

silage or root crops. The use of such feed for cows increases the milk flow beyond the actual feeding value of the food. This may be caused by its beneficial effects on the appetite of the cow, causing her to eat more than she otherwise would.

Clover and alfalfa hay contain such a large proportion of protein that they make excellent roughage for dairy cows. Corn fodder and corn stover are used extensively as roughage. There is a great variety of concentrates fed for milk production. The cow needs a variety in order to keep her appetite on edge, and on that account it may be best to purchase one of the meals or some of the by-products. Most dairymen favor feeding a small quantity of linseed or cottonseed meal. Bran, shorts, oats, corn, and barley are the concentrates most generally depended upon.

Amount of Feed. — As has been indicated before, the dairy cow should have a maintenance ration and in addition then be fed according to the amount and quality of product that she produces. A cow that gives a large quantity of rich milk should be fed more than one that gives a smaller product of low fat content.

A rough and ready rule for determining the amount of feed to be given is stated thus: feed the cow all the roughage that she will eat up clean, and give her one pound of concentrates for each three pounds of milk that she produces. It is far better, however, to figure out a balanced ration according to the feeding standards and know that each cow is getting just what she should have to maintain the body and to produce the milk.

If cows are housed in uncomfortable barns or are not treated kindly, the ration for maintenance must

be increased. It requires heat that comes from the consumption of food to make up the loss of heat sustained by poor housing, or through drinking ice-cold water.

Feeding Beef Cattle. — Feeding beef cattle for the market is more economically done when the animals are young and growing. Some protein should be given to furnish the growing tissues, but after full growth is obtained a fat-forming ration should be supplied. The principal food in the ration for fattening cattle is corn. Feeders of experience have found that steers gain more rapidly in weight and form fat more economically if given foods that are palatable even though they may be rich in protein. Some protein is necessary to supply needed nitrogen, and it may serve to produce better assimilation of other foods eaten. On this account oil meal is often given as a part of the ration for fattening steers.

Note. — The following rations have been fed successfully in fattening steers in different parts of the country:

FOR STEERS WEIGHING 1000 LB.

15 lb. clover hay
16 lb. corn silage
13 lb. corn meal
3 lb. wheat bran
_____

8 lb. alfalfa hay
12 lb. corn meal
5 lb. ground oats
_____

5 lb. mixed timothy and clover
30 lb. silage
13 lb. oats and peas

_____
8 lb. mixed hay
12.5 lb. corn meal
3 lb. wheat bran
2 lb. oil meal

_____
5 lb. clover hay
50 lb. beet pulp
11 lb. corn meal
2 lb. cottonseed meal

Purchase of Feeds. — The price of beef in this country does not warrant the purchase of feeds altogether for

feeding cattle. One who has pasturage and a quantity of roughage and grain grown on the farm may profitably use it by converting it into beef.

Feeding Swine. — Hogs will convert the products of the farm into flesh more economically than any other farm animal. Besides this, many by-products of the farm and of the dairy that would otherwise be lost may be used in producing pork. Formerly hogs were kept until they were one or two years old before being sent to the market; this made an animal, when fattened, from 300 to 500 pounds in weight. The market now pays quite as much per hundred for the smaller hog, weights from 150 to 250 pounds being accepted by the pork packers. There is much more profit also to the farmer in fattening these smaller pigs for the shorter period. The greatest profit is secured by utilizing pastures for early growth with a relatively small amount of grain and then finishing the hog on grain, preferably corn.

To produce the fat pig, a wide ration containing a relatively large supply of carbohydrates should be fed. For the growth of bone and of body and to make a healthful condition of the body protein foods should not be neglected.

Dairy Wastes. — Skim milk and buttermilk are probably the best means of furnishing the nitrogenous element necessary for raising young pigs most economically. Whey contains milk sugar, which provides carbohydrates. If with the dairy wastes there is added corn or barley, we probably have the ideal feed. In dairy regions the growing of pigs from the by-products of the dairy makes a very profitable business.

Corn Feeding. — The great dependence of the farmer for fattening hogs is on corn. This contains a large proportion of carbohydrate material and will put fat on the hog very rapidly if reënforced with some protein foods. If the price of corn is low, it may be profitable to finish the fattening process with corn alone. An exclusive corn ration during the growing period is likely to result in a weakened constitution and a consequent invitation to disease.

To furnish the requisite amount of ash, hogs should have before them at all times a mixture of charcoal, ashes, and a small amount of salt. Ground bone is also valuable for furnishing mineral matter.

Because of the extensive use of corn in pork production there has grown up a relation between the price of corn and of pork. As a rule, a high price for corn means a correspondingly high price for pork. Numerous experiments have been made to determine the amount of gain in weight of a hog that may be credited to a given quantity of corn fed under ordinary conditions. It has been agreed that one bushel of good corn will produce a gain of about 10 pounds in the weight of a hog during its growing and fattening period. The marketing of corn through the hog will usually be found to be the best way to get a maximum price for the corn grown on the farm.

Many feeders of cattle feed whole corn to their steers. About 15 per cent of this may pass through the animal undigested. One shote is placed in the feed lot to follow each steer so as to clean up the undigested corn, thus utilizing the waste.

Hogs may harvest the corn crop with a very little loss of corn if they are allowed to run in a part of the

corn field fenced off from the whole. The hogs are allowed to clean up one part thoroughly, then the division fence is moved to take in another portion of the field. This is called "hogging off corn." As ordinarily practiced it is a wasteful process, but by careful management the hogs may be made to gain as much from the corn consumed as if it were husked and fed in the pens, saving all the labor of husking.

Note. — The following food stuffs for fattening hogs have been used in different parts of the country with success:

In the North
- Clover
- Roots
- Pumpkin
- Corn
- Barley
- Peas
- Tankage
- Skim milk

In the West
- Alfalfa
- Kaffir corn
- Corn

In the South
- Alfalfa
- Sorghum
- Sweet potatoes
- Peanuts
- Soy beans
- Corn

The question often arises, Shall the grains be fed whole, or shall they be ground to a meal before feeding? If the feed is palatable in its natural whole condition, and if it is thoroughly masticated by the animal, it is not best to go to the expense of grinding. In general if the expense of grinding is 6 per cent of the cost of the feed, it is not a profitable operation.

Feeding Sheep. — Next to swine, sheep will return a larger gain for each unit of food consumed than any other animal. They are valuable also in cleaning up weeds and waste roughage that will not be eaten by other kinds of stock.

Growing sheep require a narrow ration to furnish the protein necessary for the increasing weight of tissue,

but for fattening mature sheep the ration may be considerably wider.

Sheep will consume hay and fodder of almost all kinds, but thrive and produce the best gains on the legumes, such as clover, alfalfa, pea straw, and bean straw. Corn is the standard feed for fattening sheep, but variety and palatability are given by mixing with it oats, bran, and linseed meal. When screenings can be obtained cheaply, thousands of sheep and lambs are fitted for the market at feeding stations near the large flour mills. The green pea pods obtained from pea-canning factories are put into silos and furnish a cheap feed for fattening sheep and lambs.

In Colorado many sheep and lambs are fed on beet pulp, a refuse of the beet sugar factories.

Feeding Horses. — The digestive apparatus of a horse, unlike that of cattle, is not adapted to the consumption of large amounts of coarse foods. From the table in the Appendix it will be noticed that a horse at heavy work requires 1.7 pounds of digestible dry matter for each 100 pounds of weight, or 17 pounds for a 1000-pound horse. To get this amount of nutriment from hay only, he would need to consume more than 40 pounds daily. This would be an impossibility and shows the necessity of giving the nutriment in a more concentrated form. Ten to twelve pounds of hay is all that a working horse should consume each day.

The most common ration for horses is made up of timothy hay and oats. Experience has shown this to be a good combination for horses. Good timothy hay is usually without dust and is relished by the horse. Oats, besides furnishing the protein necessary, act as a tonic to horses and seem to give them spirit and

life. It has been found, however, that corn may be substituted for oats and some experiments show that the horses are kept even more economically on corn than on oats. There is a popular notion that corn is too heating in its effect to be fed to horses, but there is no evidence of this except the fact that horses may be fattened easily on a corn diet. Wheat bran is also used successfully as an additional feed with corn or with oats. Silage may be fed in limited quantities and carrots are especially good for horses.

Feeding Poultry. — Poultry are omnivorous. They eat and demand, to give the best results, all kinds of feeds. When they are on free range, they pick up the foods that they need in the proper proportions. They pick up sand, pebbles, glass, shells, and lime to furnish the mineral matter that they desire. Grass, clover, and weed seeds furnish the green matter. Insects and worms furnish the animal matter, and grains furnish the solid dry matter. When poultry are kept from free range, all of these classes of foods should be furnished by the feeder.

Successful feeding for eggs in winter requires that hens should have before them, preferably in self-feeding hoppers, (a) grit, ground oyster shells, and charcoal; (b) a dry mash made by mixing a variety of ground grains to produce a balanced ration; (c) ground green bone and meat scraps; (d) steamed clover or alfalfa, roots, or other form of succulence; (e) whole grain thrown in the litter so that they will scratch for it.

Feeds furnished as stated make a ration similar to that given by free range, and if other conditions are favorable, result in a large egg production when the prices are the highest. Skim milk being rich in protein is a good drink for poultry producing eggs.

Notes. — *Compounding a balanced ration.* Suppose we wished to compound a ration for a dairy cow weighing about 1000 pounds and giving about $16\frac{1}{2}$ pounds of milk daily. We have the following feeds on hand : clover hay, corn stover, bran, corn meal, and cottonseed meal.

Now by consulting the feeding standards from the table in the Appendix, we find that such a cow as described will need for each hundred pounds of weight 2.7 pounds of dry matter, .2 pound of protein, 1.1 pounds carbohydrates, and .04 pound of fats, or ether extract, making a nutritive ratio of 1 : 6.

How shall these food elements be supplied from the foods on hand? In making up a ration for cows from 20 to 40 pounds of roughage should be supplied daily and very much less of the concentrates. Too much concentrates fed to a cow giving milk is liable to produce garget, a disease of the udder. Cottonseed meal and linseed meal should be fed with great care in amounts not to exceed 3 pounds daily.

With these facts in mind, let us make up a ration and compare it with the requirements given in the standard.

TRIAL RATION

Food	Lb. Fed Daily	Dry Matter	Pro- tein	Carbo- hydrate	Fat or Ether Ext.	Nutri- tive Ratio
Red clover hay . . .	15 lb.	12.7	1.07	5.72	.27	1 : 5.8
Corn stover	7.5 lb.	4.4	.15	2.48	.04	1 : 20.
Bran	2.5 lb.	1.5	.3	1.02	.07	1 : 3.7
Corn meal	3 lb.	2.5	.007	1.95	.1	1 : 10.2
Cottonseed meal . . .	1 lb.	.9	.37	.16	.12	1 : 1.2
Total		22.	1.897	11.33	.60	1 : 6.6
Standard for 1000-lb. cow		27.	2.	11.	.4	1 : 6.

From the table the weight of food elements expressed in decimals of a pound must be multiplied by the number of pounds selected in the ration.

When these amounts are added we have the total nutrients to com-

pare with the standard.   It will be observed that the ration is short of
dry matter 5 pounds.   This is not of much consequence.   It is slightly
lacking in protein and is slightly in excess of the requirement for carbo-
hydrates and fats.   The nutritive ratio is found by multiplying the
weight of fats by $2\frac{1}{4}$, adding the product to the weight of carbohydrates
and dividing the sum by the weight of protein $(.6 \times 2.25 + 11.33)$
$\div 1.897 = 6.6$.   The ratio of protein to carbohydrates is $1 : 6.6$.

This indicates that the ratio is a little too wide to conform to the
standard.   By looking at it carefully it becomes evident that it might
be slightly changed in a number of ways to make it conform more
nearly to the standard.   A few more pounds of clover, which has a
narrower ratio, might be added, at the same time reducing slightly the
amount of corn meal.   Other changes might be made that would give
the same result.   The ration as it stands is not bad at all.   It is not
expected that the ration will be made to conform exactly to the standard.
The protein content, however, should not vary much from the standard,
and on account of the cost of nitrogenous foods, should be slightly less,
rather than more, than is there given.   It requires considerable study
and the exercise of good judgment to make up the best feeding ration
from a given number of foods.

Make a ration for dairy cow weighing 900 pounds, giving 22 pounds
of milk a day, from the following: red clover hay, linseed meal, oats,
and corn silage.   If your first guess does not make a ration that con-
forms to the standard fairly well, try again, varying the weight of the
several foods to give the nutrients required.

Exercises. — (1.) Make a ration for a dairy cow weighing 850
pounds and giving $27\frac{1}{2}$ pounds of milk daily, from the following
feeds: timothy hay, corn silage, linseed meal (new process), and
wheat shorts.

(2) Make a balanced ration for a 1200-pound horse at moderate
work from the following: timothy hay, wheat bran, and oats.

(3) Make a ration for fattening sheep averaging 175 pounds in
weight, from corn silage, bran, and oats.

(4) A farmer fed each of his cows, averaging 1000 pounds in
weight, about 10 pounds of timothy hay, 16 pounds of sorghum silage,
and 4 pounds of corn and cob meal daily.   He was getting an average
of 150 pounds of butter from his cows for the year.   Suggest some

changes that might be made in this ration that would better the results.

(5) A stock feeder buys steers, weighing about 900 pounds, to fatten. What amounts of corn fodder, old process, oil meal, and wheat bran should be used during the main period?

(6) If I have 200 pounds of separator skimmed milk to feed daily to 10 growing hogs, weighing 150 pounds each, what quantities of corn and wheat bran should be used with the milk to give the best results?

(7) Make a ration for feeding 100 pounds of Wyandotte laying hens, each hen averaging 6 pounds in weight, using wheat, beef scraps, steamed red clover hay, and oats.

(8) Make up rations for the different classes of stock in the neighborhood, using the feeds that are available on the farm.

Note. — The cost of feeds should be considered in compounding a ration. It may be more profitable to feed an unbalanced ration than to feed a balanced one, depending on the price of certain feeds. Unless the price of feeds is carefully considered, one may feed a balanced ration at a constant loss.

CHAPTER IX

FARM MANAGEMENT

By Professor Andrew Boss, Minnesota Experiment Station

UNDER the term *farm management* is included the conduct of the business of a farm in connection with actually growing the various crops and classes of live stock. The one who directs or is responsible for the management is termed the *farm manager.*

Farm management in its best interpretation means the application of progressive scientific and business principles to the business of farming.

The farm manager holds the same relation to the farm and its business as does the business manager to the store or other business enterprise; that is, he is the one responsible for the success or failure of the enterprise from the financial point of view. Therefore, he must know every detail of crop growth, of cost of production, of marketing, of operating, and of all business transactions performed in connection with the farm.

Farming is a business, and the one who can grow the largest crops of the best quality and at the same time produce them at the lowest cost, sell them at the highest price, and make the best investment of the money received should rank as the best farm manager. While farming has not commonly been regarded as a business, the fact remains that the successful financial operation of a farm presents a more complex problem and

involves at least as much business ability and tact as is required in operating a store or mercantile establishment doing the same volume of business.

A farmer must have a knowledge of the elements of soil fertility, of the principles of the movement of soil water, of soil bacteria and their action, of plant growth, of varieties and species of plants, of the effect of one crop on the crop following, and of the care of seeds and forage.

He must also understand animals and how to feed and care for them, and in addition he must know how to buy and sell to advantage, to make contracts, and to plan his buildings and farm so as to economize labor and distribute it to advantage.

The farm manager who would successfully conduct his business may profit by the example of the merchant. The merchant takes an inventory of his stock, considers the demand for his goods, both present and prospective, notes the supply and cost of each article of commerce, the labor required to operate his business and any other items of expense that may be legitimate to the business, and regulates his purchases and prices accordingly. If the business is large, it is organized into departments with the labor and accounting so systematized as to show the profit or loss from each department and from the business as a whole. The farm manager should likewise take an inventory of his capital, stock, and equipment. He should consider the fertility of the soil and the demands that will be made upon it by the crops grown, the sources from which fertility may be renewed and at what cost; he must study the markets and demands for the various crops and the possibility of handling them at a profit;

the cost of producing each of the crops, including the labor supply, the interest on investment and other similar expenditures that affect the final result, and the probable net profit that will be returned. Large farms may likewise be organized into departments and accounts kept with the cows, the pigs, the grain crops, the garden, and similar enterprises. The business statement at the end of the year will then show which lines have been most profitable and will enable the manager to drop out those that are unprofitable.

INVESTMENTS

On no other one thing does financial success rest so strongly as on wise investments. One may pay so much for a farm that it will be impossible to produce revenue enough to meet the operating expenses and pay even the normal interest on the money invested. Again, one may invest in a farm which will produce well, but for the product of which there is no available market, and the business is consequently operated at a loss; or the farmer may invest so much in the farm itself that not enough capital is available for operating the farm well. A medium-sized farm well operated will pay greater profits than a large one poorly managed.

Farm machinery is looked upon as one of the means of reducing the cost of production, in that it saves man labor and enables the farmer to handle large acreages; and yet many farmers are driven out of their homes by the foreclosure of mortgages given for farm machinery for which they had little use. Too often farmers purchase machinery because a neighbor has it rather than because carefully made calculations show that it would be a profitable investment. A safe rule is to buy no

machine until careful calculation indicates that the cost of production of a certain crop or product will be reduced thereby.

Note. — If the average annual cost for a corn harvester is $18.62, the acre cost for machinery is 62 cents, if 30 acres are cut, which is cheaper than hand cutting can usually be done. If only 10 acres are cut yearly, the acre cost for machinery will be $1.86, which is considerably beyond the cost of cutting by hand.

The acre cost of harvesting on small fields would be less were the corn harvested by hand, but the wisdom of harvesting corn quickly when matured and the possibility of avoiding frost by cutting large amounts with machinery must be also considered. The larger the acreage to be cut, the cheaper becomes the cost of machinery an acre, though the labor cost will remain about the same.

Cutting Corn with Machine vs. by Hand

Corn binder, value $125.00:

Annual depreciation,	$12.50
Interest on depreciated investment,	4.12
Repairs, shelter, insurance,	2.00
Total annual cost,	$18.62

Corn raised, 20 acres:

Machinery cost an acre,	.93

Cost an acre of harvesting corn with corn harvester:

Machinery cost,	.93
Cutting and binding (horse and man labor),	.666
Shocking and tying,	.526
Picking up ears,	.249
Twine,	.467
Total cost an acre,	$2.838

Cost an acre of harvesting corn by hand 1 acre a day each man:

Labor including board — $2.60 a day,	$2.60
Twine — general expense,	.10
Total	$2.70

Farmers are often tempted to invest money in buildings which are not called for by the probable returns from the investment. It should be borne in mind that buildings in themselves are unproductive unless they house animals, crops, machinery, or products that are especially benefited by the protection. Here, again, the revenue to be derived or the profits to be gained should be carefully calculated before the investment is made. In fact, good business policy dictates that in every transaction on the farm, even to the purchase of a cow or the erection of a fence, the cost should be compared with the increased income probable from the investment.

Annual Cost of Shelter for Each Animal

A

Cost of barn 36 × 100 ft.		$4000.00
Provides shelter for 40 head of cattle.		
Annual cost,	Interest	6.0 %
	Insurance	.5 %
	Depreciation	3.0 %
	Paint and repairs	1.5 %
	Total annual cost	11.0 %

11.0 per cent on $4000.00 equals $440.00, annual cost.

$440.00 distributed over 40 head of cattle equals $11.00, the annual cost a head for shelter alone.

The cost a head in this case is exorbitant, and only first-class cows of high producing capacity can consistently be sheltered in such a barn. If the same barn were so constructed as to shelter the horses and sheep and to house grain, hay, and other products, the expense might be warranted by the greater returns from the investment.

It is possible to build a barn for $1500 to $2000 that will comfortably shelter 40 cows, in which case the annual cost a cow would be greatly reduced.

B

Cost of barn	. . . .	$2000.00
Annual cost,	Interest	6.0 %
	Insurance	.5 %
	Depreciation	3.0 %
	Paint and repairs	1.5 %
	Total annual cost	11.0 %

11.0 per cent on $2000 equals $220.00, annual cost.

$220.00 distributed over 40 cows equals $5.50 annual cost a head, or a saving of $220.00 yearly in cost of producing milk.

FARM LABOR

The labor question presents one of the most difficult problems in the management of a farm. Labor properly employed should produce returns in excess of its cost. The value of a good farm manager lies quite as much in his ability so to select and direct labor that it will yield a profit, as it does in his ability to drive a good bargain or sell his crops well. The only reason for employing labor is to increase the product and consequent profit.

While the farmer does not usually consider his time nor the time of the members of his family who participate in the work of the farm as an item of cost, he should do so and should so direct such labor as to secure at least the ordinary rate of wages for farm help for the time of himself and the members of his family who contribute to the operation of the farm.

The adjustment of labor so as to provide constant employment throughout the year is one of the difficult problems of the farm. Where a single line of farming is followed, as grain raising, labor is in strong demand only at certain seasons of the year, resulting in high

wages at that time. Rotation of crops combined with stock raising or other specialties distributes the demand for labor over the year, resulting in more constant employment of the labor of the farmer and his family and in a more uniform wage rate for hired labor. The farm manager who can so arrange his system of farming that hired labor will be needed when it can be cheaply employed and dispensed with when in strong demand should have no difficulty in securing a profit from the employment of labor. In determining the profits from the farm, all items of labor cost must be charged against the enterprises for which labor is used. Thus board must be added to the rate of wages in the neighborhood to get the full cost of labor, as the hired laborer usually lives with the family.

METHOD OF DETERMINING RATE OF WAGES AN HOUR FOR ALL FARM LABOR EXCEPT DAY WAGES

(From Table 111, Bulletin 48, Bureau of Statistics, U. S. Dept. of Agr.)

Northfield Route, Month of August, 1904

OWNER OF FARM	NAME OF LABORER	HR.	WAGES	BOARD	TOTAL	RATE PER HOUR
John Jones	James Cheney	278	$25	$10	$35	12.59
Geo. Marsh	Peter Johnson	296½	20	10	30	10.12

Northfield Route, Month of December, 1904

| John Jones | James Cheney | 222 | $12 | $10 | $22 | 9.99 |
| Geo. Marsh | Peter Johnson | 316½ | 15 | 10 | 25 | 7.89 |

Horse labor as well as man labor should be charged against the enterprise for which it is used. The rate at which it should be charged

may be ascertained by adding the cost of feed, shoeing, and labor cost of care, interest on the money invested and depreciation, dividing the sum by the number of hours worked during the year by each horse. It is easily possible to keep more horses than the labor of the farm requires, resulting in an item of loss to the farm. With horse labor also it is important that the farm operations be so arranged that a minimum amount of work will be uniformly in demand through the year.

Many farmers barely make farm wages for themselves after paying interest on the capital invested. Whether wages for labor are high or low makes little difference with the farm labor problem. Unless the manager is able to use the labor employed to as good advantage as his competitors, or even better, there will be but little profit in employing it.

Farm Planning

The cost of operating a farm can often be greatly reduced by a careful arrangement of the fields and farmstead.

The farmstead being the center of activity should be so located as to give easy and direct access to all of the fields. It is a point of economy, though not often practiced, to have each field border directly on the farmstead so that men and teams can begin work at once upon leaving the barns instead of driving 80 to 160 rods before entering the field. The amount of travel saved in this way is surprising to one who has not calculated the difference. The arrangement of the fields themselves as to shape and size is another feature which bears directly on the convenience and economy of operating the farm. A long and comparatively narrow field is more easily worked than a square one because less time is lost in turning corners. A square field, however, requires less fencing than a long one. These two opposing factors must, therefore, be adjusted and the best plan decided upon.

Where the topography of the land will allow, it is best to divide the farm into a number of equal sized fields so that a like amount of the various crops may be grown each year, thus providing for the constant employment of labor and allowing a systematic arrangement of the farm business. The time lost in traveling to and from the fields must be charged against the earning power of the field or farm. Thus a farm near by and well planned may be worth $5 an acre more than one of equal producing power, but distant and poorly planned. As the cost of operating is less, the earning capacity is greater.

Arrangement of Fields showing Value of a Well-made Farm Plan

(By courtesy of A. D. Wilson)

The following diagrams illustrate a 160-acre farm, all of which is tillable, as it was operated and as it is now being operated.

Fig. 235.

Fig. 236.

As it was operated :		As it is now operated :	
Total fencing . . .	892 rods	Total fencing . . .	640 rods
Average distance from farmstead to fields	69.9 rods	Average distance from farmstead to fields .	24 rods
		Difference in fencing required	252 rods

To raise corn on 30 acres the greatest distance from farmstead will require:

Manuring	. . . .	240 trips
Plowing	. . . .	20 trips
Harrowing	. . . .	9 trips
Disking	. . . .	8 trips
Planting	. . . .	6 trips
Cultivating	. . . .	40 trips
Husking	. . . .	30 trips
Total	. . . .	353 trips

If each trip is 172 rods, 353 trips will make 190 miles, additional travel. Equal to $19 cash in time consumed.

Note. — *Fencing.* Ten acres of land contains 1600 square rods. In a square field 160 rods of fencing would be required to inclose it, but such a field would be expensive to work on account of the large amount of turning necessary. If the field were made 10 × 160 rods, 340 rods, or 180 rods additional, fence would be required. The depreciation of this amount of additional fence and the cost of keeping up the fence would indicate that a compromise between these two, extremes would be wise. A field 20 × 80 rods would be the medium.

A well-arranged farmstead is also instrumental in greatly reducing the cost of operating the farm. When the number of trips and the time consumed is calculated, one realizes the importance of well-arranged buildings and yards. On most farms 1095 trips will be made yearly between the feed barns and the swine pens. If the pens are 5 rods farther from the barns than is necessary, 10,950 rods, or 34.2 miles, of unnecessary travel will be entailed. The saving of time that may be made in connection with doing the chores on a modern diversified farm is large and becomes an important factor in the net earnings of the business.

MANAGEMENT OF THE SOIL

Part of the business of the farm manager consists in preserving the fertility of the land and in improving the condition of the soil as far as possible. Fertility

is often lost and land rendered less valuable through erosion of the soil. On rough, hilly land and in light soils the loss from this source often becomes serious. The valuable surface soil is washed into the ravines and valleys, the fields become gullied and difficult to work, and are consequently unproductive. Erosion can be prevented to a large extent by keeping the land in grass a good portion of the time, thus filling the soil with roots, by the addition of manures, and by plowing, planting, and cultivating across the face of the hills instead of up and down the hills.

CROP ROTATION

The proper rotation of crops is regarded as essential in keeping up the producing power of the soil. It also becomes an important factor in the profit from farming because of its bearing on the farm labor and on the constant employment of capital as well as upon the fertility of the fields. Farm crops are divided roughly into three classes so far as their effect on the soil is concerned. These classes are: (1) grain crops, including all of the cereals grown for the grain they produce; (2) grass crops, including all of the crops usually grown for pasture or hay; and (3) the cultivated crops in which are included corn, potatoes, root crops, and any others which are so grown as to call for intertillage.

The grain crops are practically neutral in regard to the addition or reduction of the amount of decaying vegetable matter, or humus, in the soil and may be grown continuously for a few years without apparently affecting soil productivity. Long-continued grain cropping, however, results in weedy fields and lessened

yields from depleted fertility. Grass crops are regarded as humus-building crops and are, therefore, valuable in building up the crop-producing power of the land, especially when the grass crops are fed on the farm and the manure is hauled on the land. The decaying roots aid in opening up the subsoil, affording better underdrainage and more free entrance of air. The roots and leaves also add to the vegetable matter of the soil.

Cultivated crops are useful in clearing the land from weeds, but are destructive of humus; if continued on the same land for a few years, they will rapidly reduce the producing power of the land.

The best farm practice calls for the arrangement of these three classes of crops in a systematic scheme of cropping which brings them in succession on each field of the farm.

Some of the crops upon each farm are used for feed; others are sold for cash and removed entirely from the farm. The system of farming which provides for the use of all of the crops on the farm as food, selling the product in the form of live stock or live stock products is most conservative of the fertility of the farm.

Suggestions on Crop Rotation. — A good scheme of crop rotation implies the division of the farm into a number of fields of nearly uniform size. Ordinarily, there should be a field for each year in the rotation, that is, a three-year rotation will be best followed if the farm is divided into three fields, or a five-year rotation if the farm is divided into five fields. Such a division of the farm distributes the crops each year and makes uniform the labor required and the product received. Consequently, the labor can be adjusted to the needs of the business.

If live stock is kept, the cropping system can be so arranged as to lessen the work in summer and increase it in the winter when farm labor is comparatively cheap, thus increasing the profit. No scheme

of rotation can be given that will apply to all farms, as the crops must be adapted to the soil, climate, markets, and local conditions in each instance.
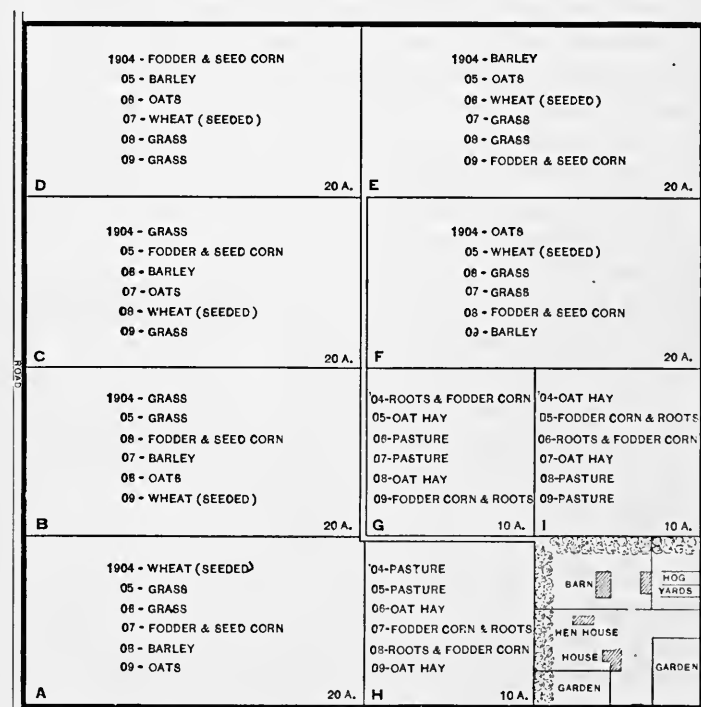
FIG. 237. — Plan of Farm arranged for a Six-year Major Rotation and a Six-year Minor Rotation adapted to Three Small Fields.

Cost of Production. — The cost of production of each crop in the rotation should be considered in all cases where figures are available. The Bureau of Statistics, United States Department of Agriculture, has published two bulletins, Numbers 48 and 73, which give valuable figures on this subject, gained from an extensive study of farm operations in Minnesota made in coöperation with the Minnesota Experiment Station.

Cost an Acre of Corn Production

Seed	$.226
Shelling seed	.026
Plowing	1.311
Dragging	.544
Planting	.240
Cultivating	1.806
Husking	3.456
Machinery cost	.549
Land rent	3.500
General expense	1.000
	$12.658

In the above calculation land is valued at $70.00 an acre, upon which interest at the rate of 5 per cent is charged. Man labor varied from 12 cents to 13.5 cents an hour; horse labor averaged 9.25 cents an hour, and all horse and man labor included are charged at these rates. One half the cost of manuring is charged to the corn crop on a somewhat arbitrary basis and is included under general expense. The general expense of the farm, charged on a pro rata basis, is about $1.00 an acre, and this figure is used for the corn field.

Accounting

If a farm is to be conducted as a business enterprise, it follows that some system of accounting must be adopted which will permit a close analysis of each enterprise conducted.

An inventory should be taken at the end of each year as a basis of comparison of the business for the year. An account should be opened with each crop grown, as wheat, oats, corn, hay, or orchard, also with the various classes of live stock, as cows, swine, sheep, poultry, or horses, and with all labor also, and each enterprise charged with the amount consumed in carrying forward the work. While it would be possible to learn

whether the farm as a whole had been profitable by charging all items of expense against it and crediting the farm with all produce raised, such an account would be of little value in learning which lines or enterprises were affording the profit. Therefore, it is deemed necessary to open an account with each enterprise, just as a storekeeper opens an account with each customer. Against each enterprise must be charged all items of expense, such as man and team labor at the cost of furnishing such labor, machinery, cost, and depreciation, land rental, or interest, and anything else that may add to the cost of production. The enterprise should be credited with all revenue arising from the product whether sold or used as food. If used as food, it should be credited at the market price for such products in the neighborhood. The difference between the debit and credit accounts will show whether the enterprise has been profitable. If unprofitable after a fair trial, the methods should be corrected or the enterprise dropped for a more profitable one.

The form of accounts should be as simple as possible so as to demand little time. A card ledger account with each enterprise, upon which may be entered directly all charges or credits, will be found convenient and suited to most forms of business. The balances from the various enterprises show the profit or loss from each, and when brought together on a balance sheet show the profit or loss from the farm as a whole.

APPENDIX

Weights of Grain, Seeds, Etc.

The table given below shows the weight of grain, seeds, etc., per bushel, as established by the legislatures of the states named:

Articles	New York	Ohio	Pennsylvania	Indiana	Wisconsin	Iowa	Illinois	Michigan	Connecticut	Massachusetts	Rhode Island	Kentucky	New Jersey	Vermont	Missouri	Minnesota
Wheat	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Rye	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56
Corn	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56
Oats	32	32	32	32	32	32	32	32	32	32	32	32	30	32	32	32
Barley	48	48	47	48	48	48	48	48	48	48	48	47	48	48	48	48
Buckwheat	48	50	48	50	48	52	52	48	48	48	48	56	50	48	52	50
Clover Seed	60	64	60	60	60	60	60	60	..	..	60	60	64	60	60	60
Timothy Seed	45	45	..	45	45	45	45	45	..	.	45	45	..	45	45	45
Flax Seed	55	46	..	56	55	56	56	56	..	..	56	56	55	..	44	56
Hemp Seed	44	44	..	44	44	44	44	44	..	..	40	44	..	..	44	50
Blue Grass Seed	14	..	..	14	14	14	14	14	..	..	..	14	14	..	..	14	14
Apples, Dried	25	24	..	25	28	24	24	22	..	..	..	24	25	..	24	28
Peaches, Dried	33	33	..	33	28	33	33	28	..	..	..	39	33	..	32	28
Coarse Salt	56	50	85	50	..	50	..	..	..	..	..	50	..	..	50	56
Fine Salt	56	50	63	50	..	50	..	..	..	..	..	50	..	..	50	56
Potatoes	60	60	56	60	60	60	60	60	60	60	60	60	60	60	60	60
Peas	60	..	..	..	60	..	60	60	60	60	60	60	60	60	60	60
Beans	60	60	..	60	60	60	60	60	60	60	60	60	60	62	60	60
Castor Beans	46	..	..	46	..	46	46	46	..	..	..	..	..	..	46	..
Onions	57	55	50	48	57	57	57	54	50	50	50	57	57	52	57	52
Corn Meal	50	..	..	50	50	..	48	50	50	50	50	..	..	..	50	..

Plowing

Breadth of Furrow Slice Inches	Distance Traveled in Plowing an Acre Miles
7	$14\frac{1}{2}$
8	$12\frac{1}{4}$
9	11
10	$9\frac{9}{16}$
11	9
12	$8\frac{1}{4}$
13	$7\frac{1}{2}$
14	7
15	$6\frac{1}{4}$
16	$6\frac{1}{8}$
17	$5\frac{3}{4}$
18	$5\frac{1}{2}$
19	$5\frac{1}{4}$
20	$4\frac{9}{16}$

FEEDING STANDARDS FOR DAILY RATIONS

Class of Animal	Unit	Description	Total Dry Matter	Digestible Nutrients				Nutritive Ratio
				In Pounds and Decimal Fractions Thereof				
			A	Protein *B*	Carbohydrates *C*	Fat (ether extract) alone	Total *D*	*E*
Growing dairy cattle	Each head	Age in mo. Live wt, lb.						
		2–6 150	3.45	0.60	1.95	0.300	3.28	1 to 4.5
		3–6 300	7.20	0.90	3.84	0.300	5.42	1 to 5.1
		6–12 500	13.50	1.00	6.81	0.250	7.81	1 to 6.8
		12–18 700	18.20	1.26	8.75	0.280	10.64	1 to 7.5
		18–24 900	23.40	1.35	10.79	0.270	12.76	1 to 8.5
Growing beef cattle	Each head	2–3 165	3.80	0.69	2.14	0.330	3.58	1 to 4.2
		3–6 330	7.92	1.10	4.23	0.495	6.51	1 to 4.7
		6–12 550	13.75	1.38	7.27	0.385	9.52	1 to 6.0
		12–18 750	18.00	1.50	9.35	0.375	11.70	1 to 6.8
		18–24 935	22.44	1.68	11.21	0.374	13.74	1 to 7.2
Fattening beef cattle	For each 100 lb. live weight	Preliminary period........	3.00	0.25	1.30	0.050	1.86	1 to 6.5
		Main period	3.00	0.30	1.45	0.070	1.91	1 to 5.4
		Finishing period	2.60	0.27	1.50	0.070	1.93	1 to 6.2
Milch cows	For each 100 lb. live weight	Milk yield, 11 lb. daily......	2.50	0.16	1.00	0.030	1.23	1 to 6.7
		Milk yield, 16½ lb. daily....	2.70	0.20	1.10	0.040	1.39	1 to 6.0
		Milk yield, 22 lb. daily......	2.90	0.25	1.29	0.050	1.66	1 to 5.7
		Milk yield, 27½ lb. daily.....	3.20	0.33	1.30	0.080	1.81	1 to 4.5
Work oxen	For each 100 lb. live weight	At rest	1.80	0.07	0.79	0.010	1.00	1 to 11.8
		Light work	2.20	0.14	1.00	0.030	1.00	1 to 7.7
		Moderate work	2.50	0.20	1.14	0.050	1.00	1 to 6.5
		Heavy work	2.80	0.28	1.48	0.080	1.00	1 to 5.3
Horses	For each 100 lb. live weight	Light work	2.00	0.15	0.95	0.040	1.10	1 to 7.0
		Moderate work	2.40	0.20	1.10	0.060	1.44	1 to 6.2
		Heavy work	2.60	0.25	1.33	0.080	1.76	1 to 6.0

	Each head basis	Age in mo. Live wt., lb.						
Growing wool sheep	Each head	4–6 60	1.50	0.20	0.92	0.042	1.22	1 to 5.0
		6–8 75	1.88	0.21	1.03	0.045	1.35	1 to 5.4
		8–11 ... 85	1.96	0.18	0.97	0.043	1.25	1 to 6.0
		11–15 .. 90	1.98	0.16	1.00	0.036	1.25	1 to 7.0
		15–20 .. 100	2.20	0.15	1.08	0.030	1.30	1 to 7.7
Growing mutton sheep	Each head	4–6 65	1.69	0.29	1.06	0.035	1.43	1 to 4.0
		6–8 85	2.21	0.30	1.27	0.060	1.71	1 to 4.8
		8–11 ... 100	2.40	0.30	1.42	0.050	1.84	1 to 5.2
		11–15 .. 120	2.76	0.26	1.50	0.060	1.90	1 to 6.3
		15–20 .. 150	3.30	0.30	1.80	0.060	2.24	1 to 6.5
Fattening sheep	For each 100 lb. live weight	Preliminary period	3.00	0.50	1.50	0.050	1.91	1 to 5.4
		Main period	2.80	0.35	1.45	0.060	1.94	1 to 4.5
Mature sheep	For each 100 lb. live weight	Coarse wool	2.00	0.12	1.05	0.020	1.22	1 to 9.1
		Fine wool	2.30	0.15	1.20	0.030	1.42	1 to 8.5
		Ewes, suckling lambs	2.50	0.29	1.50	0.050	1.90	1 to 5.6
Growing breeding swine	Each head	Age in mo. Live wt., lb.						
		2–3 45	1.98	0.34	1.25	0.045	1.70	1 to 4.0
		3–5 100	3.50	0.50	2.31	0.080	2.99	1 to 5.0
		5–6 120	3.84	0.44	2.55	0.048	3.10	1 to 6.0
		6–8 175	4.90	0.49	3.28	0.053	3.89	1 to 7.0
		8–12 ... 260	6.50	0.55	3.86	0.052	4.53	1 to 7.5
Growing fattening swine	Each head	2–3 45	1.98	0.34	1.25	0.045	1.70	1 to 4.0
		3–5 110	3.85	0.55	2.54	0.088	3.99	1 to 5.0
		5–6 150	4.95	0.65	3.35	0.090	4.21	1 to 5.5
		6–8 200	6.00	0.72	4.10	0.080	5.00	1 to 6.0
Fattening swine	For each 100 lb. live weight	Preliminary period	3.60	0.45	2.50	0.070	3.11	1 to 5.9
		Main period	3.20	0.40	2.40	0.050	2.91	1 to 6.3
		Finishing period	2.50	0.27	1.80	0.040	2.16	1 to 7.0
Mature swine	For each 100 lb. live weight	Brood sows	2.20	0.25	1.55	0.040	1.89	1 to 6.6
Poultry	For each 100 lb. live weight	Maintenance hens, 3 to 5 lb.	3.90	0.50	2.95	0.30	4.13	1 to 7.4
		Hens, 5 to 8 lb.	2.70	0.40	2.00	0.20	2.85	1 to 6.2

DIGESTIBLE NUTRIENTS AND FERTILIZING CONSTITUENTS OF VARIOUS FEEDING STUFFS

Total Dry Matter in 1 lb.	Digestible Nutrients in 1 lb.			Nutrient Ratio Protein to Carbohydrates and Fats	Food	Fertilizer Content in 1000 lb.			
	Protein	Carbohydrates	Fat (Ether Extract) Alone			Nitrogen in 1000 lb.	Phosphoric Acid in 1000 lb.	Potash in 1000 lb.	Manurial Value in T. of 2000 lb.
In Decimal Fractions of One Pound						lb.	lb.	lb.	
					Green Fodders:				
.383	.012	.191	.006	1 to 17.0	Timothy	4.8	2.6	7.6	$2.31
.349	.030	.198	.008	1 to 7.2	Kentucky Blue Grass				
.289	.020	.160	.004	1 to 8.4	Hungarian Grass	3.9	1.6	5.5	1.77
.347	.021	.212	.006	1 to 10.8	Redtop				
.270	.015	.113	.005	1 to 8.3	Orchard Grass	4.3	1.6	7.6	2.06
.282	.039	.126	.005	1 to 3.5	Alfalfa	7.2	1.3	5.6	2.74
.292	.029	.148	.007	1 to 5.6	Red Clover	5.3	1.3	4.6	2.49
.166	.018	.087	.002	1 to 5.1	Cowpeas	2.7	1.0	3.1	1.16
.249	.032	.109	.005	1 to 3.8	Soy Beans	2.9	1.5	5.3	1.44
.234	.021	.141	.004	1 to 7.1	Rye Fodder	3.3	1.5	7.3	1.72
.210	.019	.102	.004	1 to 5.8	Barley Fodder				
.378	.026	.189	.010	1 to 8.2	Oat Fodder	4.9	1.3	3.8	1.90
.160	.018	.071	.002	1 to 4.2	Oats and Peas				
	.017	.072	.002	1 to 4.5	Barley and Peas				
.207	.010	.116	.004	1 to 12.5	Green Corn Fodder	4.1	1.5	3.3	1.64
.206	.006	.122	.004	1 to 21.8	Green Sorghum Fodder	2.3	0.9	2.3	0.96
.140	.015	.081	.002	1 to 5.7	Rape	4.5	1.5	3.6	1.79
.269	.014	.166	.005	1 to 13.0	Barnyard Millet	6.1	11.9	4.1	2.35
.193	.021	.093	.004	1 to 4.8	Crimson Clover	4.7	1.2	3.9	
.209	.009	.113	.007	1 to 14.3	Corn Silage	2.8	1.1	3.7	1.25
.239	.006	.149	.002	1 to 25.6	Sorghum Silage				
.207	.015	.085	.009	1 to 7.0	Cowpea Silage				
.258	.027	.086	.013	1 to 4.3	Soy Bean Silage				

2.09	4.6	1.3	5.3	Clover Silage	1 to 7.9	.010	.135	.020	.280
5.03	9.0	5.3	12.6	Alfalfa Silage	1 to 4.3	.019	.085	.030	.275
				Hay and Straw:					
7.05	18.8	3.3	17.4	Timothy Hay............	1 to 16.6	.014	.434	.028	.868
5.23	15.7	4.0	11.9	Mixed Grass and Clover..	1 to 6.5	.015	.383	.064	.859
5.84	18.8	4.1	13.1	Kentucky Blue Grass Hay.....	1 to 8.7	.020	.373	.048	.788
4.99	13.0	3.5	12.0	Orchard Grass Hay	1 to 9.2	.014	.423	.049	.901
				Hungarian Hay	1 to 12.0	.013	.510	.045	.923
				Barnyard Millet Hay.....	1 to 5.5	.010	.377	.072	.890
5.74	15.5	2.7	14.1	Mixed Grass Hay.......	1 to 7.4	.012	.409	.059	.871
6.45	14.9	4.3	16.1	Mixed Rowen..........	1 to 5.5	.015	.401	.079	.834
8.42	16.8	5.1	21.9	Alfalfa Hay...........	1 to 3.8	.012	.396	.110	.916
8.35	22.0	3.8	20.7	Red Clover Hay	1 to 5.8	.017	.357	.068	.847
9.47	22.3	6.7	23.4	Alsike Clover Hay	1 to 5.4	.015	.425	.084	.903
7.55	14.7	5.2	19.5	Cowpea Hay...........	1 to 3.8	.011	.385	.108	.893
8.49	10.8	6.7	23.2	Soy Bean Hay	1 to 3.9	.015	.388	.108	.887
4.63	10.2	3.6	11.5	Vetch Hay............	1 to 3.1	.031	.336	.129	.887
				Redtop Hay	1 to 10.3	.010	.469	.048	.911
				Oat Hay..............	1 to 11.6	.015	.464	.043	.911
				Oat and Vetch Hay	1 to 5.0	.004	.384	.078	.869
6.53	8.9	5.4	17.6	Corn Fodder (Field Cured)	1 to 14.9	.012	.346	.025	.578
4.53	14.0	2.9	10.4	Corn Stover (Field Cured)	1 to 20.0	.007	.324	.017	.595
5.85	9.8	2.9	17.6	Peanut Hay	1 to 7.2	.030	.419	.068	.924
2.30	5.1	10.2	5.9	Wheat Straw	1 to 93.0	.004	.363	.004	.904
3.05	12.4	2.6	6.2	Oat Straw	1 to 33.6	.008	.386	.012	.908
5.90	20.9	3.0	13.1	Barley Straw	1 to 60.8	.006	.412	.007	.858
2.29	7.9	2.8	4.6	Rye Straw............	1 to 69.1	.004	.406	.006	.929
5.46	10.2	3.5	14.3	Pea Vine Straw.........	1 to 7.9	.008	.323	.043	.864
6.71	13.2	4.0	17.5	Soy Bean Straw.........	1 to 18.4	.010	.400	.023	.899
				Kaffir Corn Stover	1 to 24.0	.009	.414	.018	.808
3.93	10.6	2.5	22.5	White Clover	1 to 3.9	.014	.418	.115	.903

SEED PLANTING IN THE UNITED STATES

(Compiled from reports of the Department of Agriculture)

New England

Kind of Crop	Date of Planting	Best Soil	Amount of Manure per Acre	Amount of Seed per Acre	Weeks to Maturity
Corn	May 10 to 30	Sandy or clay loam	8 to 12 tons	8 to 12 qt.	14-17
Wheat	Fall or Spring	Clay loam	18 tons	2 bush.	20
Oats	April to May	Strong loam	6 to 8 tons	2 to 3 bush.	11-15
Barley	April to June 20	Strong loam	7 to 8 tons	2 to 3 bush.	10-15
Rye	April to May, Sept.	Medium loam	7 to 8 tons	5 to 6 pecks	40
Buckwheat	June 1 to 20	Light loam	4 to 6 tons	1 to 1¼ bush.	10-15
White Beans	May to June	Sandy loam	7 to 8 tons	8 to 16 qt.	8 14
Potatoes	April 15 to May 1	Rich loam	15 to 20 tons	8 to 20 bush.	12-20
Turnips	July 1 to Aug. 3	Sandy loam	10 tons	1 lb.	10
Mangels	April 15 to May 5	Strong, heavy loam	8 to 15 tons	4 to 6 lb.	17 22
Tobacco	Seed bed, April	Sandy loam	8 to 12 tons	....	9-12
Hay	....	....	....	....	......

Middle States

Kind of Crop	Date of Planting	Best Soil	Amount of Manure per Acre	Amount of Seed per Acre	Weeks to Maturity
Corn	April 20 to May 30	Medium loam	8 to 12 tons manure	6 to 8 qt.	16-18
Wheat	Sept. 20 to Oct. 20	Loam	8 tons; 300 lb. fer.	2 bush.	4-43
Oats	March to May	Moist clay loam	8 tons; 300 lb. fer.	2 to 2½ bush.	16-17
Barley	March to May	Clay loam	8 tons; 300 lb. fer.	2 to 2½ bush.	13-16
Rye	Sept. 1 to Oct. 1	Sand or gravel loam	8 tons; 300 lb. fer.	1½ bush.	40-43
Buckwheat	June to July	Loam	5 tons	¾ to 1¼ bush.	8-10
White Beans	May to June	Sandy loam	8 tons	1½ bush.	13 14
Potatoes	March to May	Loam	10 to 18 tons	8 to 15 bush.	14-22
Sweet Potatoes	May to June	Sandy loam	....	10 to 12 bush.	10-15
Cabbage	March to July	Clay or sandy loam	300 to 600 lb. fer.	4 to 8 oz.	8-15
Turnips	July	Loam	....	2 to 5 lb.	10-12
Mangels	May	Loam	10 to 20 tons	10 to 15 bush.	15-18
Flax	May	Limestone loam	....	20 qt.	8-10
Tobacco	Seed bed, March	Sandy loam	Commercial fer.	....	15-20
Hay, Timothy	Aug. to Oct.	Clay loam	....	6 to 8 qt.	......
Hay, Clover	Feb. to April	Clay loam	....	6 qt.	......

CENTRAL AND WESTERN STATES

Kind of Crop	Date of Planting	Best Soil	Amount of Manure per Acre	Amount of Seed per Acre	Weeks to Maturity
Corn	April 1 to June	Black or sandy loam	5 to 10 tons	6 qt.	16-20
Wheat	Fall or Spring	Strong loam	8 tons	2 bush.	40-42
Oats	April 1 to May	Clay loam	8 tons	2 to 3 bush.	12-14
Barley	Fall or Spring	Clay loam	8 tons	2 bush.	11-13
Rye	Sept. 1 to 30	Light loam	8 tons	1 to 2 bush.	35-40
Buckwheat	June	Clay loam	5 tons	1 to 2 bush.	1-12
White Beans	May 10 to June 10	Clay loam	8 tons	1½ bush.	12
Potatoes	March 15 to June 1	Sandy loam	5 to 10 tons	5 to 10 bush.	10-20
Turnips	July 15 to Aug. 30	Loam or muck	8 to 10 tons	1 to 6 lb.	10-16
Mangels	April 1 to May 15	Sandy loam	8 to 12 tons	6 to 8 lb.	22-24
Flax	March 15 to May 15	Loam	10 to 15 tons	2 to 3 pecks	15-20
Tobacco	Seed bed, March	Sandy loam	8 to 10 tons	oz. to 6 sq. rd.	15-18
Hay	April to May	Clay loam	10 tons	8 to 15 lb.	.....

SOUTHERN STATES

Kind of Crop	Date of Planting	Best Soil	Amount of Manure per Acre	Amount of Seed per Acre	Weeks to Maturity
Cotton	Feb. to May 15	Sandy loam	.....	1 to 3 bush.	20-30
Corn	Feb. to June	Rich loam	10 bush. cot. seed	8 qt.	18-20
Wheat	Sept. to Nov.	Clay loam	8 tons	2 bush.	43
Oats	Feb., May, Sept.	Clay loam	8 to 10 tons	2¼ bush.	17
Barley	April to May	Clay loam	10 tons	2 bush.	17
Rye	Sept. to Oct.	Light loam	8 tons	1½ bush.	43
White Beans	March to May	Light loam	6 to 10 tons	1 to 2 bush.	7-8
Cabbage	Oct., March to May	Rich, light loam	5 tons; 300 lb. fer.	¼ to ½ lb.	16-20
Watermelons	March 1 to May 10	Loam or muck	.....	2 to 7 lb.	14
Onions	Feb. 1 to April 10	Light, loose loam	.....	.....	16-20
Potatoes	Jan., Feb. to April	Sandy loam	8 to 12 tons	8 to 10 bush.	11-15
Sweet Potatoes	May to June	Rich, light loam	.....	10 to 12 bush.	12-15
Pumpkins	April 1 to May 1	Rich, light loam	.....	4 to 7 lb.	17-20
Tomatoes	Jan. 1 to Feb. 19	Rich, sandy loam	.....	4 to 9 oz.	14-20
Turnips	Feb., Aug., April	Rich, light loam	.....	2 to 6 lb.	8-12
Tobacco	Seed bed, March	Sandy loam	8 to 15 tons	oz. to 6 sq. rd.	18-20
Cowpeas	May 1 to July 15	Sandy loam	200 to 300 lb. phos.	2 to 5 pecks	6-8
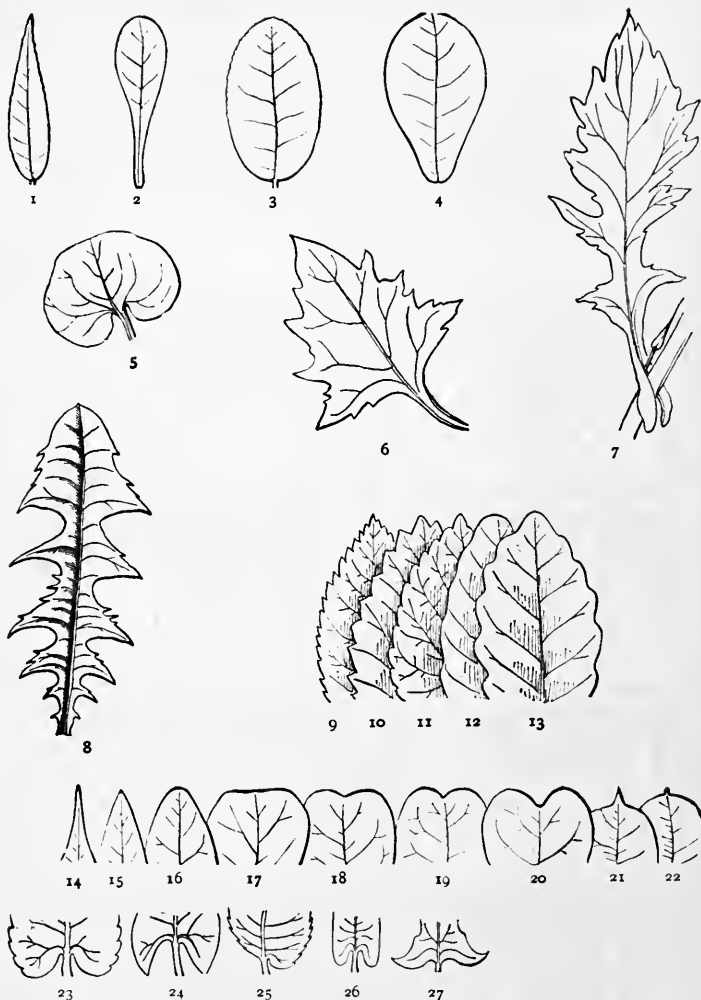
1, lanceolate; 2, spatulate; 3, oval; 4, obovate; 5, reniform; 6, deltoid; 7, lyrate; 8, runci-nate; 9, serrate; 10, dentate; 11, crenate; 12, undulate; 13, sinuate; 14, acuminate; 15, acute; 16, obtuse; 17, truncate; 18, 19, emarginate; 20, obcordate; 21, cuspidate; 22, mucronate; 23, cordate; 24, sagittate; 25, oblique; 26, auricled; 27, hastate.

Diagram of Cow.

1. Head.
2. Muzzle.
3. Nostril.
4. Face.

5. Eye.
6. Forehead.
7. Horn.
8. Ear.
9. Cheek.
10. Throat.
11. Neck.
12. Withers.
13. Back.
14. Loins.
15. Hip bone.
16. Pelvic arch.
17. Rump.
18. Tail.
19. Switch.
20. Chest.
21. Brisket.
22. Dewlap.
23. Shoulder.
24. Elbow.
25. Forearm.
26. Knee.
27. Ankle.
28. Hoof.
29. Heart girth.
30. Side or barrel.
31. Belly.
32. Flank.
33. Milk vein.
34. Fore udder.
35. Hind udder.
36. Teats.
37. Upper thigh.
38. Stifle.
39. Twist.
40 Leg or gaskin
41. Hock.
42. Shank.
43. Dew claw.

Diagram of Sheep.

1 Head.
2. Face.
3. Muzzle.
4. Nostril.
5 Eye.
6. Ear.
7. Cheek.
8. Neck.
9. Withers.
10. Throat.
11. Back.
12. Loins.
13. Angle of ilium.
14. Rump.
15. Tail or Dock.
16. Chest.
17. Shoulder.
18. Elbow.
19. Forearm.
20. Knee.
21. Ankle.
22. Claw.
23 Girth measure.
24. Side or barrel.
25. Belly.
26. Flank.
27. Hip joint.
28. Stifle joint.
29. Hock joint.

Diagram of Horse.

0. Poll or nape of the neck.
1. Neck.
1'. Jugular gutter.
2. Withers.
3. Back.
4. Loins.
5. Croup.
6. Tail.
7. Parotid region.
8. Throat.
9. Shoulder.
10. Point of the shoulder.
11. Arm.
12. Elbow.
13. Forearm.
14 Chestnut.
15 Knee.
16 Canon.
17. Fetlock.
18. Pastern.
19. Coronet.
20. Foot.
21. Xiphoid region.
22. Ribs.
23. Abdomen.
24. Flank.
25. Sheath.
26. Testicles.
27. Buttock.
27 bis. Angle of buttock.
28. Thigh.
28 bis. Haunch.
29. Stifle.
30. Leg.
31. Hock.
32. Chestnut.
33. Canon.
34. Fetlock.
35. Pastern.
36. Coronet.

1. Comb.
2. Face.
3. Wattles.
4. Ear lobes.
5. Hackle.
6. Breast.
7. Back.
8. Saddle.
9. Saddle feathers.
10. Sickles.
11. Tail coverts.
12. Main tail feathers.
13. Wing bow.
14. Wing coverts, forming wing bar.
15. Secondaries, wing bay.
16. Primaries or flight feathers; wing buts.
17. Point of breast bone.
18. Thighs.
19. Hocks.
20. Shanks or legs.
21. Spur.
22. Toes or claws.

Diagram of Chicken.

ELEMENTS AND INTERNATIONAL ATOMIC WEIGHTS

Name	Symbol	Atomic Weights $O = 16$	Name	Symbol	Atomic Weights $O = 16$
Aluminium	Al	27.1	Mercury	Hg	200.0
Antimony	Sb	120.2	Molybdenum	Mo	96.0
Argon	A	39.9	Neodymium	Nd	144.3
Arsenic	As	74.96	Neon	Ne	20.0
Barium	Ba	137.37	Nickel	Ni	58.68
Beryllium or Glucinum	Be } Gl }	9.1	Nitrogen	N	14.01
			Osmium	Os	190.9
Bismuth	Bi	208.0	Oxygen	O	16.0
Boron	B	11.0	Palladium	Pd	106.7
Bromine	Br	79.92	Phosphorus	P	31.0
Cadmium	Cd	112.40	Platinum	Pt	195.0
Cæsium	Cs	132.81	Potassium	K	39.10
Calcium	Ca	40.09	Praseodymium	Pr	140.6
Carbon	C	12.0	Radium	Ra	226.4
Cerium	Ce	140.25	Rhodium	Rh	102.9
Chlorine	Cl	35.46	Rubidium	Rb	85.45
Chromium	Cr	52.0	Ruthenium	Ru	101.7
Cobalt	Co	58.97	Samarium	Sa	150.4
Columbium or Niobium	Cb } Nb }	93.5	Scandium	Sc	44.1
			Selenium	Se	79.2
Copper	Cu	63.57	Silicon	Si	28.3
Dysprosium	Dy	162.5	Silver	Ag	107.88
Erbium	Er	167.4	Sodium	Na	23.0
Europium	Eu	152.0	Strontium	Sr	87.62
Fluorine	F	19.0	Sulphur	S	32.07
Gadolinium	Gd	157.3	Tantalum	Ta	181.0
Gallium	Ga	69.9	Tellurium	Te	127.5
Germanium	Ge	72.5	Terbium	Tb	159.2
Gold	Au	197.2	Thallium	Tl	204.0
Helium	He	4.0	Thorium	Th	232.42
Hydrogen	H	1.008	Thulium	Tm	168.5
Indium	In	114.8	Tin	Sn	119.0
Iodine	I	126.92	Titanium	Ti	48.1
Iridium	Ir	193.1	Tungsten	W	184.0
Iron	Fe	55.85	Uranium	U	238.5
Krypton	Kr	83.0	Vanadium	V	51.2
Lanthanum	La	139.0	Xenon	Xe	130.7
Lead	Pb	207.10	Ytterbium (Neoytterbium)	Yb	172.0
Lithium	Li	7.0			
Lutecium	Lu	174.0	Yttrium	Y	89.0
Magnesium	Mg	24.32	Zinc	Zn	65.37
Manganese	Mn	54.93	Zirconium	Zr	90.6

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